Guide for the testing and evaluation of timber connection Category C

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Australian Engineered Fasteners and Anchors Council

Contents

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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 as Category C fasteners as defined in this document.

The current Australian Standard for testing and evaluation of timber connections is *AS 1649: 2025 Timber - Methods of test for mechanical fasteners and connectors - Basic working loads and characteristic strengths*. The procedures in AS 1649 represent a 'soft' conversion from working stress design to limit states design, resulting in limited transparency and restricted coverage.

This Guide adopts a prototype testing methodology for deriving characteristic values directly from test data in line with limit state design. It also introduces modifications and clarifications to the testing procedures, informed by international practice, including *ANSI/TPI 1-2022, National Design Standard for Metal Plate Connected Wood Truss Construction*.

This Guide is intended to assist suppliers of Category C fasteners in providing characteristic values and appropriate capacity factors for use in design, to be used together with, or in place of, the information provided in *AS 1720.1 Timber structures - Part 1: Design methods* and *AS 1720.1 Timber structures – Part 5: Nailplated timber roof trusses.*

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 C fasteners as defined in this document.

The purpose of testing is to determine the load-deformation characteristics of the connection to define the capacity 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, 2022). 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:

- Category C fasteners installed in a factory-controlled environment.
- Sawn timber, glulam, and LVL without finger joints where the Category C fasteners are installed.
- 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.
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.
4. The ultimate capacity can be defined by either maximum load capacity or load capacity at a defined deformation.

1.2 Definitions

Category C fasteners: are defined in AS 1649 as fasteners acting as gussets or splice plates capable of transferring load from the face of one member to the face of another, where the two faces involved lie in the same plane, see Figure 1. In addition, this Guide considers Category C fasteners as those that consist of a flat metal plate with integral teeth that are punched from the same base material. They are commonly referred to as 'metal connector plates', 'toothed fasteners', 'toothed plates', or 'nailplates' and are embedded into the timber members to form the required joint.

> COMMENT: Unlike AS 1649, this guide does not include nails on metal plate (i.e., metal connector plates without integral teeth) due to the difference in their behaviour and testing requirements. Nails on metal plates can be designed using provisions in AS 1720.1.

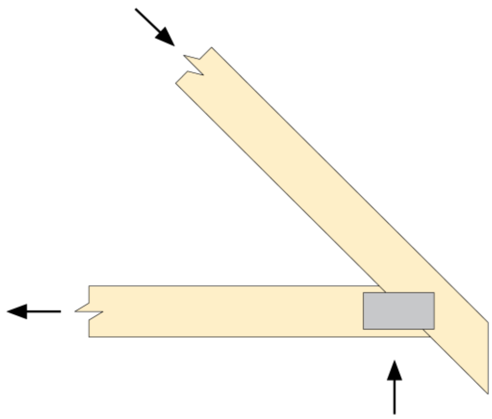


Figure 1: Category C fasteners

Characteristic value: The value of a property taken to represent that of the reference population. In this Guide, for failure in timber (see Section 4.1), the characteristic value is taken to be the 5-percentile value with 75% confidence based on a lognormal distribution unless defined otherwise. For failure in metal (see Section 4.2), the characteristic value is a 5-percentile value at 99% confidence with Weibull distribution to be used with a capacity factor of 1.0 in accordance with the *NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria.*

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.

Tooth group: Tooth groups identify the category of timber for which the tested values apply. Classification is based on parameters such as timber species, grain structure, and density. Unlike other fastener types, Category C fasteners penetrate only to a shallow depth in the timber member; therefore, joint groups (which are based on average density of the timber) are not suitable. The categorisation of tooth groups is not generic and determined by the fastener supplier.

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.

1.3 Notations

The following symbols are used in this Guide.

d_{pr}	=	dimension of the metal connector plate perpendicular to the direction of the load, this dimension should correspond to the minimum width of the metal connector plate when the width is reduced to ensure failure occurs at this location
k_{mod}	=	modification factors as specified in AS 1720.1
k_m	=	sampling factor for metal failure
k_t	=	sampling factor for timber failure
l_s	=	calculated shear length of the metal connector plate
n	=	number of test values
N	=	total number of teeth acting in one member of the joint.
P_y	=	yield load resistance from the test data
P_{max}	=	maximum load from the test data
P_{plate}	=	load for one connector plate from the test data
$P_{specimen}$	=	load applied to the specimen
P_t	=	ultimate load resistance from the test data, corresponding to maximum load or the load at acceptable maximum deformation
$\overline{P}_t$	=	mean value of the ultimate load resistance from the test data
$P_{t,i}$	=	ultimate load resistance from the test data for test value i
$P_{t,plate,i}$	=	ultimate load resistance for one metal connector plate from the test data for test value i
R_d	=	design capacity
R_k	=	characteristic value of the resistance of the fastener, i.e., characteristic capacity
V_a	=	coefficient of variation as the result of theory accuracy when compared with experimental data
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 of the reference population
V_t	=	coefficient of variation of the test results
δ_{acc}	=	acceptable maximum deformation, corresponding to deformation at which the connection is considered to have failed or is unsuitable for its application
δ_{max}	=	deformation corresponding to the maximum load (P_{max})

δ_y	=	deformation corresponding to the yield load resistance (P_y)
δ_t	=	deformation corresponding to the ultimate load resistance (P_t)
$\delta_{t,i}$	=	deformation corresponding to ultimate load resistance for test value i
$\overline{\delta_t}$	=	mean value of the deformation corresponding to the ultimate load resistance from test data
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. Each specimen shall be tested using a testing machine of suitable capacity

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 less than or equal to 15%.

> 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 indoors in laboratory conditions. The temperature at time of testing should be recorded.

1.4.5 Time of testing

The specimens shall be kept for at least seven days after assembly, including the installation of fasteners, before testing to allow for relaxation of the materials.

> COMMENT: For seasoned timber, a period of seven days is generally sufficient to allow material relaxation after fastener installation. A longer period of 14 days is recommended for unseasoned timber.

1.4.6 Moisture content and density

The moisture content and density of each specimen shall be determined at the time of testing in accordance with AS/NZS 1080.1 and AS/NZS 1080.3, respectively. Moisture content shall be measured using either the over-dry method or a moisture content meter.

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 tooth group for test specimens

The reference population represented by the test specimens is highly dependent on the properties of the timber members. Tooth groups are used for Category C fasteners to identify the timber category for which the tested values apply, with classification based on parameters such as species, grain structure, and density. Unlike other fastener types, Category C fasteners penetrate only to a shallow depth in the timber member; therefore, joint groups (which are based on average density of the timber) are not suitable. The categorisation of tooth groups is not generic and determined by the fastener supplier. It is necessary to consult the fastener supplier's documentation to ensure the correct application of design values for Category C fasteners for a given timber type.

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.

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 where the failure is in the timber. For tests conducted to cause failure in the metal, a minimum of five test values (i.e., n=5) is recommended. Each suggested test specimen will result in one test value. The same failure mode shall be observed for all specimens in a test series.

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 appropriate geometry of the fasteners used in tests shall be provided.

COMMENT: Any modification to the fastener's structural profile and material properties may influence connection performance; therefore, any modified fasteners must be re-tested to verify its performance.

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 and species.

(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 sawn timber, the timber *members in each joint should 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)
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 tooth group;
d. Designated grade;
e. Size range of the product;
f. Moisture condition;
g. Treatment of the product;
h. Presence or exclusion of specific features in the connection (e.g., knots or finger joints); and
i. 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, including method of installation for the nailplates (e.g., pressed or rolled)
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 C 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.

It is necessary to consider:

(i) Failure in the timber: the lateral resistance of metal connector plate teeth, and
(ii) Failure in the metal: the resistance of metal connector plate under tension and shear forces

No contribution from secondary fasteners or adhesives should be used for testing.

3.2 Test specimens

The test specimens shall follow the sampling procedure described in Section 2. The moisture content and densities of the members comprising each joint shall be determined at the time of 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 following section sets out the recommended test setup for this Guide. While some aspects are consistent with AS 1649, several modifications have been incorporated.

3.3.1 Failure in timber

The method of testing for determining the lateral resistance of the metal connector plate teeth, includes:

(i) Consideration of two types of specimens, Parallel Type and Perpendicular Type. Each specimen type shall consist of two members assembled as illustrated in Figure 2. The member dimensions and the fastener locations shall be as follows:

(a) Parallel Type
- l_1 = not less than the greater of 225 mm and $3b$
- $a, b, w_1 and\ t_1$ = as specified by the manufacturer

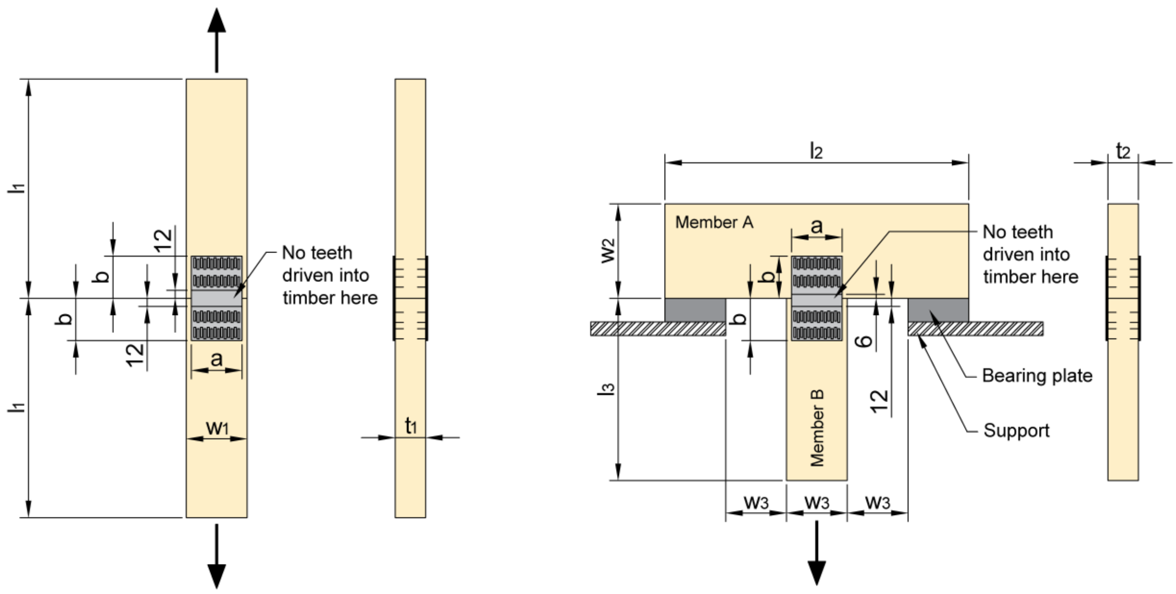
(b) Perpendicular Type
- l_2 = not less than the greater of 450 mm and $5a$
- l_3 = not less than $3w_3$
- $a, b, w_2, w_3\ and\ t_2$ = as specified by the manufacturer

(c) General
- The thicknesses of the two members forming the joint for each specimen type shall not differ by more than 2 mm
- No teeth shall be driven into the timber closer than:
  - (A) 12 mm from the butt joint for specimens of the Parallel Type and for member B of specimens of the Perpendicular Type.
  - (B) 6 mm from the butt joint for member A of specimens of the Perpendicular Type.
- Where removal of teeth is required to meet the above requirements, the plate may be ground smooth in the necessary area.

(ii) Where the properties of metal connector plates depend on plate orientation, an equal number of specimens of both the Parallel Type and the Perpendicular Type shall be prepared with the plates oriented in the two principal directions, typically at right angles to each other. However, if one of these orientations consistently results in failure of the parent metal of the fastener, minimum of five specimens with that plate orientation are required to be tested.

(iii) For specimens of the Perpendicular Type, the horizontal member A can be supported by a suitably designed saddle.

(iv) The preparation of the joints shall follow the installation of the metal connector plates in accordance with the manufacturing process, including whether the plates are to be installed using the (a) pressing, or (b) rolling method. The joints in the assembly should be close to each other but not compressed.



(a) Parallel type **(b) Perpendicular type**

Figure 2: Test specimen configuration for the lateral resistance of the teeth of Category C fasteners

3.3.2 Failure in metal

The resistance of the metal connector plate shall be determined under tension and shear forces.

3.3.2.1 Tensile strength of the plate

The method of testing to determine the tensile resistance of the metal connector plate includes the following:

(i) Using a test specimen as shown in Figure 3, or by developing a suitable alternative specimen. A suitable alternative test specimen includes one where the metal connector plate fails away from the secured edge (e.g., away from any machine grips). A test specimen shall be rejected if failure occurs, or is initiated, within 20 mm of the nearest weld or gripping point.

(ii) Five specimens shall be prepared, with metal connector plates selected at random as for the joint tests for failure in timber.

COMMENTS:

1. It is important that the specimens are prepared so that the plates are not deformed during the welding operation, that each plate is stressed uniformly, and that the line of action of the applied load aligns with the centre-line of each plate.
2. Reference may be made to AS 1391 for additional details on the tensile testing of metals, if required.

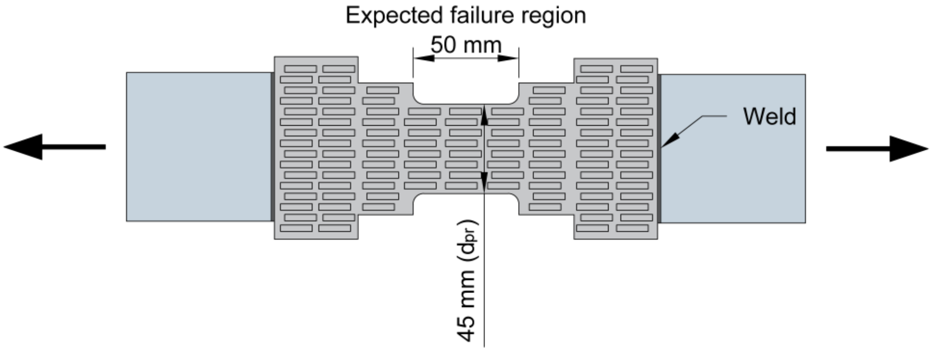


Figure 3: Test specimen configuration for the tensile resistance of the metal connector plate

3.3.2.2 Shear strength of the plate

The method of testing to determine the shear resistance of the metal connector plate includes the following:

(i) Using the relevant test specimens as shown in Figure 4. Each specimen comprises of three timber members and four identical metal connector plates. The same timber species used for failure in timber shall be used for failure in metal. The metal connector plates should be selected randomly as done for the joint tests for failure in timber. One metal connector plate is positioned on each side of the joint interface, with its length (L_p) inclined at an angle (α) to the shear plane. The recommended dimensions of the members are provided in Table 1.

(ii) Where the capacity of the metal connector plate is dependent on the plate orientation, specimens shall be prepared with the plates positioned as intended to be used in construction. The orientation of the plates is defined by the angle α. The following angles should be considered: 0°, 30°, 90°, 120°, and 150°. A zero-degree angle ($\alpha = 0$) is considered when the L_p is parallel to the joint. Angles greater than zero ($\alpha > 0$) are defined when L_p is rotated anticlockwise from the vertical position (i.e., in line with the shear plane).

(iii) For angles less than 90 degrees, the plates should be positioned so that the axial component of the force in the plates is tensile. For angles greater than 90 degrees, the plates should be positioned so that the axial component is compressive.

(iv) The metal connector plate shall be long enough to ensure failure occurs in the plate itself rather than through tooth withdrawal. If necessary, the plate may be clamped or fastened at least 50 mm away from the joint to prevent withdrawal.

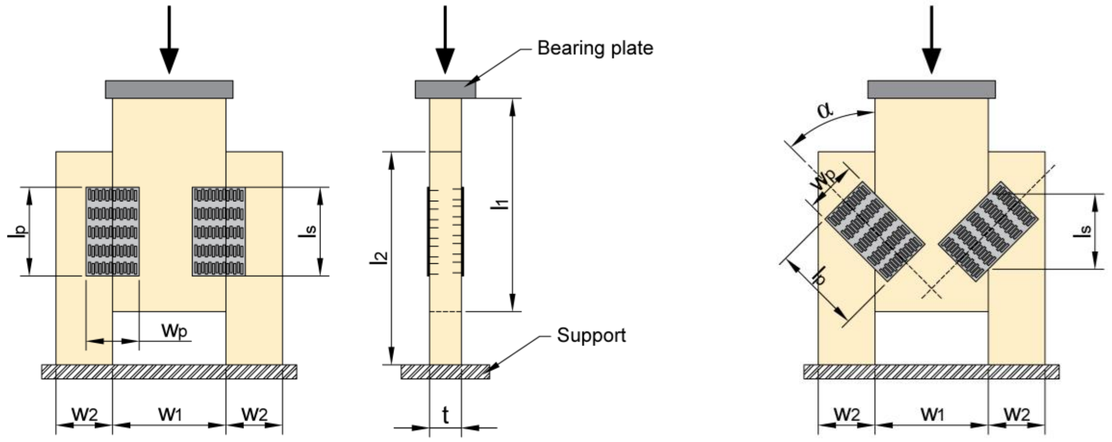
(v) The metal connector plate should be embedded into the timber without removing any teeth.

(vi) The installation procedure of the metal connector plate shall be consistent with the manufacturing process, including whether it is to be installed by pressing or rolling method. The joints in the specimen shall be close to each other but not compressed.

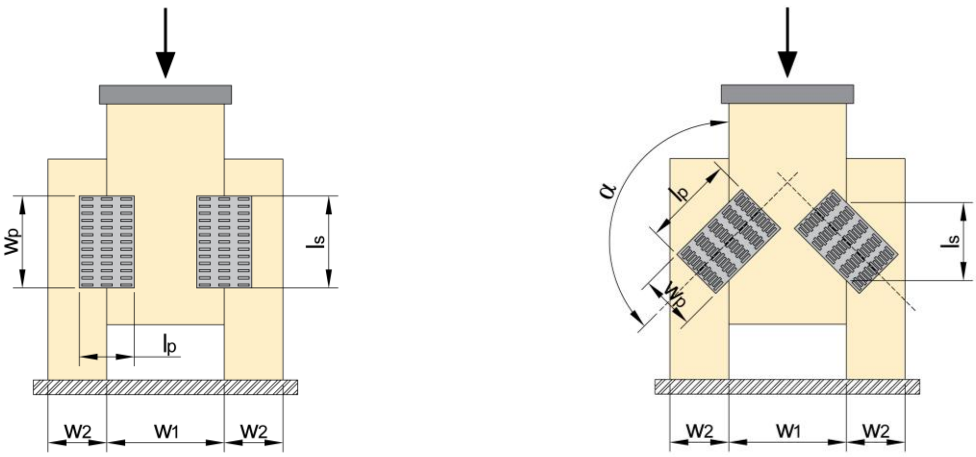
(vii) The specimens can be loaded such that it is in tension or compression. If the specimens are tested in compression, it is necessary to ensure that the members will not fail in simple compression parallel to grain at a load lower than the shear strength of the metal connector plates. It should be checked that the product $w_1 \times t$ is not less than S/f_c, where S is the expected maximum load in newtons and f_c is the compressive strength of timber.

Table 1: Recommended member dimensions for shear strength of metal connector plates

Dimension	$\alpha = 0°$	$\alpha = 90°$	For all other α
$l_1 = l_2 \geq$ the greater of 225 mm and:	$l_p + 60$ mm	$w_p + 60$ mm	$0.7(l_p + w_p)$
w_1	$\geq w_p + 5$ mm	$\geq l_p + 5$ mm	$\geq 0.7(l_p + w_p)$
w_2	$\geq w_1/2$		
t	$\geq (2.5 \times$ tooth length)		



(a) $\alpha = 0°$ orientation (b) $\alpha < 90°$ orientation



(c) $\alpha = 90°$ orientation (d) $\alpha > 90°$ orientation

Figure 4: Test specimen configuration for the shear resistance of the metal connector plate

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 is reached.

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. In such cases, where possible the load should be applied until a reduction of 30% of the maximum load is observed.

3.4.1 Failure in timber

For failure in timber, the load shall be applied at a rate such that the maximum load is reached in approximately 5 to 10 minutes.

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. It is ideal to have the peak load to be reached in five minutes as it will correspond to a load duration factor (k_1) of 1.0 in accordance with AS 1720.1:2010.
2. AS 1649 specifies applying the load at a rate of crosshead movement of 1.25 mm +/- 25% per minute for timber failure, 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.

3.4.2 Failure in metal

For failure in metal, the load shall be applied at a constant rate such that the maximum load is reached in approximately 1 to 10 minutes.

COMMENT:

AS 1649 specifies applying the load at a rate of crosshead movement of 0.3 mm +/- 10% per minute for metal failure, this can be followed if P_{max} is reached in not less than 1 minute.

3.5 Measurement of deformation

3.5.1 Failure in timber

For failure in timber, the deformation (or slip) shall be continuously measured using suitable displacement measurement devices.

The displacement measurement devices should measure joint slip under load with an accuracy of ± 1% or better, or for slip of less than 2 mm with an accuracy of ± 0.02 mm.

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

3.5.2 Failure in metal

For failure in metal, it is recommended that the deformation of the metal connector plate is measured using suitable displacement measurement devices. Where possible, two displacement measurement devices should be used on each side of the joint such that the displacement can be taken as the average of the two readings.

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.

3.6.1 Failure in timber

For Category C fasteners for failure in timber, the test ultimate resistance shall be determined from test results in accordance with Section 4.1.1.

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.

3.6.2 Failure in metal

For Category C fasteners for failure in metal, the ultimate resistance shall be determined from the test results in accordance with Section 4.2.1.

When required, the yield resistance for Category C fasteners may be determined in accordance with Appendix A.

SECTION 4
EVALUATION PROCEDURE

4.1 Failure in timber

This section describes the evaluation procedure for failure in timber to determine the lateral resistance of metal connector plate teeth.

4.1.1 Ultimate resistance and corresponding deformation from test results

For Category C fasteners for failure in timber, the test ultimate load resistance (P_t) is typically taken as the observed maximum load (P_{max}), where joint deformation limits and slips do not need to be explicitly considered. However, the procedure below is suggested for determining the test ultimate laod resistance and corresponding deformation when deformation limits and slips are critical:

(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 ultimate load 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 ultimate load resistance (δ_t) shall be noted for each test, where $\delta_t = \delta_{max}$ or $\delta_t = \delta_{acc}$.

4.1.2 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.

It is recommended that the coefficient of variation of the reference population (V_p) is taken as 20% for calculating the characteristic value from test results. A lower V_p ranging from 10% to 20% can be used if determined to be suitable based on extensive test results. However, V_p shall not be lower than the coefficient of variation of the test results (V_t) as defined by Eq. 2.

V_p can be calculated using Eq. 3 if V_a, V_m, and V_f can be determined.

$$V_t = \frac{standard\ deviation\ of\ the\ test\ results}{mean\ of\ the\ test\ results} \qquad \text{Eq. 2}$$

$$V_p = \sqrt{V_a^{\ 2} + V_m^{\ 2} + V_f^{\ 2}} \qquad \text{Eq. 3}$$

Where

V_a = coefficient of variation as the result of theory accuracy when compared with experimental data, when there is no theory V_a 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

4.1.3 Characteristic value from statistics of test results

The characteristic ultimate lateral resistance of the metal connector plate teeth shall be calculated from the test results using Eq. 4.

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.

$$R_k = \frac{\overline{P}_t}{k_t N} \qquad \text{Eq. 4}$$

Where

$\overline{P}_t$ = mean value of the ultimate load resistance from the test data.

$\overline{P}$ = $\sum_{i=1}^{n} \frac{P_{t,i}}{n}$

$P_{t,i}$ = ultimate load resistance from the test data for test value i.

n = number of test values.

k_t = sampling factor for timber failure, provided in Table 2.

V_p = coefficient of variation of the reference population of the connection, see Section 4.1.2.

N = total number of teeth acting in one member of the joint.

Table 2: Sampling factor for timber failure, k_t

No of tests, n	Sampling factor k_t for the coefficient of variation of connection reference population V_p		
	0.1	**0.15**	**0.2**
10	1.21	1.33	1.47
20	1.20	1.32	1.45
50	1.19	1.31	1.44
100	1.18	1.31	1.41

4.1.4 Determination of the capacity factor

The capacity factor (ϕ) can be calculated using the National Construction Code (NCC, 2022) Verification Method BV1 Structural Reliability. Alternatively, the capacity factors suggested in AS 1720.1 (2010) can be adopted for multitoothed nailplates, where the characteristic value is calculated in accordance with this Guide. The capacity factors in AS 1720.1 (2010) varies based on the application of the structural member as shown in Table 3.

Table 3: Capacity factor (ϕ) for Category C fasteners in accordance with AS 1720.1:2010

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.
Category C fasteners in accordance with this Guide, including multitoothed nailplates conforming to manufacturer's specification	0.85	0.80	0.75

COMMENT:

For Category C fasteners for when the failure is in the timber, the maximum allowed coefficient of variation is limited to 0.2 to ensure that the minimum structural reliability is achieved in accordance with Verification Method BV1, NCC 2022 and the capacity factors stated in Table 3 of this Guide. If the coefficient of variation is greater than 0.2, structural reliability analysis shall be conducted to determine suitable capacity factor.

4.1.5 Mean ultimate deformation from test results

Where deformation at the ultimate load is required, the mean deformation corresponding to the ultimate load resistance from test data ($\overline{\delta_t}$) should be calculated using Eq. 5.

$$\overline{\delta_t} = \sum_{i=1}^{n} \frac{\delta_{t,i}}{n} \qquad \text{Eq. 5}$$

Where

$\overline{\delta_t}$ = mean value of the deformation corresponding to the ultimate load resistance from test data

$\delta_{t,i}$ = deformation corresponding to ultimate load resistance for test value i

n = number of test values

4.2 Failure in metal

This section describes the evaluation procedure for Category C fasteners for failure in metal. The procedure is similar to NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria and AS/NZS 4600, with modifications made to suit Category C fasteners.

4.2.1 Ultimate resistance

The ultimate resistance shall be taken as either the maximum observed load or the load corresponding to an acceptable level of deformation or extension of the metal connector plate, based on the test load-deformation results.

4.2.2 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. 6, unless V_a, V_m, and V_f can be determined for which case Eq. 7 can be used.

The coefficient of variation of the reference population shall not be less than 10% or greater than 20% for calculating the characteristic value from test results.

$$V_p = \begin{cases} 0.1 & \text{if } V_t \leq 0.1 \\ V_t & \text{if } 0.1 < V_t \leq 0.2 \end{cases} \qquad \text{Eq. 6}$$

Where

V_t = coefficient of variation of the test results

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

$$V_p = \sqrt{{V_a}^2 + {V_m}^2 + {V_f}^2} \qquad \text{Eq. 7}$$

Where

V_a = 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:

V_f is dependent on the variation in geometric properties of the fasteners, generally taken as 5% in steel design practice.

4.2.3 Characteristic value from statistics of test results

The characteristic value shall be calculated using the mean value from the test results as prescribed in Section 4.2.3.1 for ultimate tensile resistance and Section 4.2.3.2 for ultimate shear resistance.

The method for determining the characteristic value follows the approach specified in the NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria, and AS/NZS 4600 when the average of the test results is used to establish the characteristic value.

The characteristic value for metal failure is representative of the for 5-percentile value at 99% confidence (assuming a Weibull distribution).

The sampling factor, k_m, for use with the average value of the test results are given in Table 4. Linear interpolation of k_m is allowed between the number of tests (n) and coefficient of variation of the reference population (V_p) provided in Table 4.

COMMENTS:

NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria and AS/NZS 4600 allow the characteristic capacity from test results to calculated from either mean test results divided by a sampling factor, or the minimum test results divided by another sampling factor. In this Guide, it is recommended that the mean test results are used for determining the characteristic value as it ensures consistent results.

Table 4: Sampling factor for metal failure (k_m) for use with average value of test results

No of tests, n	Sampling factor k_t for the coefficient of variation of connection reference population V_p		
	0.1	**0.15**	**0.2**
5	1.34	1.57	1.85
10	1.31	1.51	1.77
20	1.28	1.47	1.70
50	1.27	1.45	1.67
100	1.25	1.42	1.62

4.2.3.1 Ultimate tensile strength of the plate

The **characteristic ultimate tensile resistance per unit width of the metal connector plate** shall be calculated using Eq. 8.

$$R_k = \frac{\overline{P_t}}{k_m d_{pr}} \qquad \text{Eq. 8}$$

Where

$\overline{P_t}$ = mean value of the ultimate load resistance from test data for one metal connector plate (P_{plate}).

$P_{plate} = P_{specimen}$ for test specimen which has one plate.

$P_{plate} = \frac{P_{specimen}}{2}$ for test specimen which has two plates, one plate on each side of the joint.

$P_{specimen}$ = load applied to specimen.

$\overline{P_t}$ = $\sum_{i=1}^{n} \frac{P_{t,plate,i}}{n}$

$P_{t,plate,i}$ = ultimate strength resistance for one metal connector plate from the test data for test value i

n = number of test values

k_m = sampling factor for metal plate failure, provided in Table 4.

V_p = coefficient of variation of the reference population of the connection, see Section 4.2.2.

d_{pr} = dimension of the metal connector plate perpendicular to the direction of the load. This dimension should correspond to the minimum width of the metal connector plate when the width is reduced to ensure failure occurs at this location.

4.2.3.2 Ultimate shear strength of the plate

The **characteristic ultimate shear strength per unit length of the metal connector plate** shall be calculated using Eq. 9.

$$R_k = \frac{\overline{P_t}}{k_m l_s} \qquad \text{Eq. 9}$$

Where

$\overline{P_t}$ = mean value of the ultimate strength resistance from test data for one metal connector plate (P_{plate}).

$P_{plate} = \frac{P_{specimen}}{4}$ for test specimen which has four plates, two plates on each side of the specimen.

$P_{specimen}$ = load applied to specimen.

$\overline{P_t}$ = $\sum_{i=1}^{n} \frac{P_{t,plate,i}}{n}$

$P_{t,plate,i}$ = ultimate strength resistance for one metal connector plate from the test data for test value i

n = number of test values

k_m = sampling factor for metal plate failure, provided in Table 4.

V_p = coefficient of variation of the reference population of the connection, see Section 4.2.2.

l_s = calculated shear length of the metal connector plate (see Figure 4)

4.2.4 Determination of the capacity factor

As suggested in NASH and AS/NZS 4600, the capacity factor (ϕ) for metal failure can be taken as 1.0 when the characteristic strength is calculated in accordance with this Guide.

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, maximum load and corresponding deformation or the acceptable deformation and corresponding load, and the mode of failure for each specimen.

(ix) Summary of the results, including the characteristic value of the strength resistance of the fastener and corresponding capacity factor, and the mean deformation corresponding to the test load capacities used to calculate the characteristic strength of the fastener.

(x) Any special features or deviations that may have any effect on the test results.

APPENDIX A: Yield strength and deformation for failure in the metal

Appendix A outlines the procedure for determining yield strength resistance from testing for Category C fasteners where failure occurs in the metal.

It is recommended that the yield load is derived from the test load-deformation curve using the Yasumura and Kawai (1998) method (cited in Hubbard and Salem, 2024), which is adopted by the Architectural Institute of Japan (AIJ) Standard for steel structures.

The method for determining the yield load involves first calculating the initial stiffness of the load-deformation curve between 10% and 40% of the maximum applied load (K_{10-40}). Next, the secant stiffness between 40% and 90% of the maximum load (K_{40-90}) is established. The yield point is identified at the intersection of the initial stiffness line (K_{10-40}) and the secant stiffness line (K_{40-90}) which is drawn offset and tangent to the curve. This intersection is then projected horizontally onto the curve to determine the yield load. This is illustrated in Figure A1.

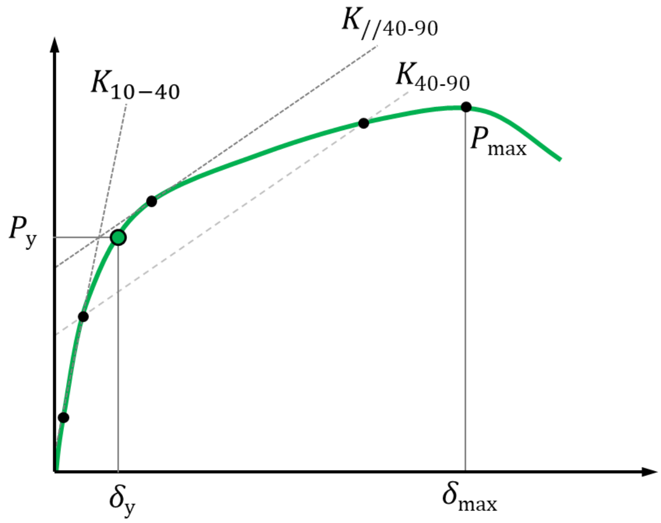


Figure A1: Method for determining the yield point on a load-deformation curve

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