Draft standard

Methods of test for mechanical fasteners and connectors
Part 2: Category C & D Fasteners
T02

Standard version # 1

Publication date 18 August 2026

FWPA Forest & Wood Products Australia

Wood Solutions™

Methods of test for mechanical fasteners and connectors Part 2: Category C & D Fasteners

FWPA Standard T02

Edition 1.0

First published: Month 2026

ISBN: xxx-x-xxxxxx-xx-x

Forest & Wood Products Australia Limited
Suite 6.03, Level 6, 36 Wellington Street
Collingwood, VIC 3066 Australia

T +61 3 9927 3200
E info@fwpa.com.au
W www.fwpa.com.au

FWPA Standard

T02 Methods of test for mechanical fasteners and connectors

Part 2: Category C & D Fasteners

Edition 1.0

Month 2026

This FWPA Standard was originally developed under a project supported by Forest and Wood Products Australia and xxx. The Standard has been taken through a formal public review process under the guidance of the established FWPA xxx Standards Writing Committee (SWC). The FWPA Standard was issued for public comment on the Day Month 202x, revised and endorsed by the SWC in Month 202x and finalised in Month 202x.

Keeping Standards up to date

FWPA Standards are living documents that reflect progress in science, technology, systems and regulations. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using the current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about FWPA Standards, drafts, amendments and new projects can be found by visiting www.fwpa.com.au.

FWPA welcomes suggestions for improvements and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities.

Amendment Schedule

Edition	Date	Description
0.0	Day Month 202x	First Edition

Preface

The research and development underpinning this FWPA Standard have been undertaken by the Australian Engineered Fasteners and Anchors Council (AEFAC). The AEFAC Guides developed for the testing and evaluation of Category C and Category D fasteners were further developed, with the support of Forest & Wood Products Australia (FWPA), to form this FWPA Standard.

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. Furthermore, the test methods in AS 1649 remain largely unchanged from those documented in the initial version of the standard published as AS A188 in 1972.

This Standard is an alternative to AS 1649:2025 for the testing and determination of characteristic capacities for specific types of commonly used timber connections. It applies to connections in sawn timber and specified engineered wood products and includes Category C fasteners (metal connector plates/nailplates) and Category D fasteners (brackets), as defined in this document.

This Standard adopts a prototype testing methodology for the direct derivation of characteristic values from test data, consistent with the principles of limit state design. It also introduces modifications and clarifications to the testing procedures specified in AS 1649 to ensure alignment with current engineering practice.

This Standard is intended to be used by suppliers of Category C and Category D fasteners to determine the characteristic values for use in the design of joints, to be used together with, or in place of, the information provided in *AS 1720.1 Timber structures, Part 1: Design methods* and *AS 1720.5 Timber structures – Part 5: Nailplated timber roof trusses.*

The testing and evaluation of Category A (nails, staples or screws) and Category B (bolts and dowels) is provided in *FWPA Standard T01, Methods of test for mechanical fasteners and connectors, Part 1: Category A & B fasteners.*

The terms 'normative' and 'informative' are used in this Standard to define the application of the appendix. A "normative" appendix is mandatory, whereas an "informative" appendix is non-mandatory and provided as information and guidance.

All statements in this Standard are mandatory, with notes and commentary provided as information and guidance.

Contents

Section 1 Scope and General Requirements

1.1 Scope

This document specifies the methods for testing timber connections incorporating mechanical fasteners and the procedures for the evaluation of the test data to obtain design information for timber connection Category C and Category D 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 document describes the derivation of the characteristic value of the resistance of the fastener (R_k, i.e., characteristic capacity). It is to be used with suitable capacity factors (ϕ) and 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 document 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 document is limited to:

- Category C fasteners installed in a factory-controlled environment;
- Seasoned timber;
- Sawn timber, glued-laminated timber (glulam), and laminated veneer lumber (LVL) without a finger joint over the entire cross-section where the Category C fasteners are installed. The installation of Category C fasteners in glulam with staggered finger-jointed lamellas is permitted at any location along the member; and
- Sawn timber, glulam, and LVL for Category D fasteners.

NOTE 1 The characteristic values can only be defined for an applicable or reference population of connections with reference to a failure mode.

NOTE 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 need 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).

NOTE 3 'Prototype testing methodology' means: (i) full-size specimens should be used in testing, and (ii) the test specimen should be designed to suit the purpose of the test.

NOTE 4 Ultimate failures can be defined by either maximum load capacity or load capacity at a defined deformation.

NOTE 5 Category D fasteners may be used to join timber with other non-timber members. This document is only applicable for timber members.

1.2 Referenced documents

The following documents are referred to in this Standard:

AEFAC Guide for the testing and evaluation of timber connection Category C

AEFAC Guide for the testing and evaluation of timber connection Category D

AS 1391: (ISO 6892-1) Metallic materials – Tensile testing – Method of test at room temperature

AS 1649 Timber - Methods of test for mechanical fasteners and connectors Basic working loads and characteristic strengths

AS 1720.1 Timber structures Part 1: Design methods

AS 1720.5 Timber structures Part 5: Nailplated timber roof trusses

AS 2193 Calibration and classification of force-measuring systems

AS/NZS 1080.1 Timber - Methods of test Part 1: Moisture Content

AS/NZS 1080.3 Timber - Methods of test Part 3: Density

AS/NZS 4600 Cold-formed steel structures

FWPA Standard T01, Methods of test for mechanical fasteners and connectors, Part 1: Category A & B fasteners.

NASH Standard Residential and low-rise steel framing, Part 1 Criteria

1.3 Definitions

Category C fasteners: fasteners consisting of a flat metal plate with integral teeth punched from the same base material, which act as gussets or splice plates capable of transferring load from the face of one member to the face of another, where the two faces lie in the same plane, see Figure 1. 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.

NOTE This document 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.

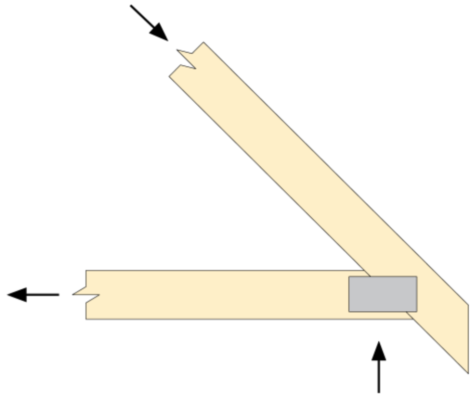


Figure 1 Category C fasteners

Category D fasteners: fasteners acting as brackets capable of transferring load from the face of one joint member to the face of another, where the two faces involved usually lie in planes at right angles to each other, see Figure 2. They consist of a pre-formed metal component attached to the structural member with metal fasteners such as nails, screws, and bolts.

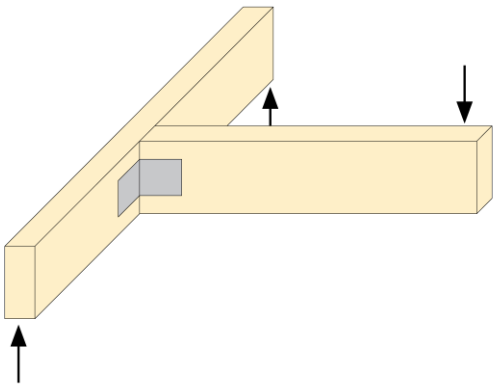


Figure 2 Category D fasteners

Characteristic value: The value of a property taken to represent that of the reference population. In this document:

(i) For failure in timber, the characteristic value is taken to be the 5-percentile value with 75% confidence based on a lognormal distribution unless defined otherwise (see Section 4.2.4),

(ii) For failure in metal, the characteristic value is taken to be the 5-percentile value at 99% confidence with Weibull distribution (see Section 4.3.3).

Connection: A structural component or system comprising either a single fastener or an assembly of fasteners to transfer loads between timber members.

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: Used inter-changeably with the term connector.

Joint group: The classification of timber based on timber density and whether it is seasoned or unseasoned.

Joint: Used inter-changeably with the term connection.

Population: All of the structural timber product that meets the specification of the product.

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

NOTE 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.

Sample: The number of single members of the population, selected to represent the reference population.

Specimen: A 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.

Tooth group: Tooth groups identify the category of timber for which the tested values for Category C fasteners 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.

1.4 Notations

The following symbols are used in this document.

a_v	=	modification factor for variation
d_{pr}	=	dimension of the metal connector plate perpendicular to the direction of the load, this dimension shall 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	=	member length
l_s	=	calculated shear length of the metal connector plate
n	=	number of test values
t	=	member thickness
w	=	member width
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
$\bar{P}_t$	=	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
$P_{tc,i}$	=	corrected value of the ultimate load resistance from the test data for test value i corrected to refer to $\rho_{m,ref}$
$P_{t,plate,i}$	=	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
$\bar{\delta}_t$	=	mean value of the deformation corresponding to the ultimate load resistance from test data
$\rho_{m,ref}$	=	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

1.5 Conduct of tests

1.5.1 Apparatus

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.

The displacement measurement devices shall 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.

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

1.5.2 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 representative conditions of the actual service conditions of the connection in the structure.

When the purpose of the testing is to compare the performance of connections, then the standard conditions as described in Section 1.5.3 and 1.5.4 shall be used for the specimen conditions and test environment conditions, respectively.

1.5.3 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%.

NOTE 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.

1.5.4 Test environment for standard conditions

The test shall be conducted indoors in laboratory conditions. The temperature at time of testing shall be recorded.

1.5.5 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.

NOTE 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.

1.5.6 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 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.

1.5.7 Number of specimens

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

1.6 Assignment of joint group and 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 are not suitable. The categorisation of tooth groups is not generic and determined by the fastener supplier. The tooth groups shall be consistent with those specified in the supplier's documentation to ensure the correct application of design values for Category C fasteners for a given timber type.

Joint groups are used for Category D fasteners to identify the timber category for which the tested values apply, with classification based on the mean air-dry density of the timber. For seasoned timber, there are six joint groups (JD1 to JD6) as shown in Table 1.

The mean density of the timber members of the specimens selected to represent the joint group shall be lower than the group average density. All timber members of the test specimens shall be within the group density range in Table 1 or in a joint group of a lower density range.

Where appropriate, a correction to the test results for the timber density of the samples shall be applied as specified in Section 4.2.2 for Category D fasteners.

Table 1 Mean density range for joint groups for seasoned timber at 12% moisture content

Joint group	Group density range (kg/m^3)	Group average density (kg/m^3)
JD1	> 940	-
JD2	750 to 935	842.5
JD3	600 to 745	672.5
JD4	480 to 595	537.5
JD5	380 to 475	427.5
JD6	300 to 375	337.5

1.7 Design of the test program and evaluation of results

This section describes the general principles to follow for the design of the test program and evaluation of the test results.

(i) Sampling procedure

The sampling shall be in accordance with Section 2.

(ii) Testing procedure

The general testing procedure principles shall be in accordance with this section and the specific requirements as stated in Section 3.

The test setup, including the specimen configurations, supports for the specimen, and application of the load, shall represent the actions corresponding to the actual service conditions of the connection.

NOTE 1 This Standard provides test setups suitable for typical applications of Categories C and D fasteners. It is essential to verify that the selected setup is appropriate for the specific fastener type and application under investigation. Where the proposed setup is not fully representative, exploratory testing should be undertaken to provide insight into connection behaviour and to inform the development of an appropriate test program. Such *investigations should consider relevant parameters including expected failure modes, sampling requirements, test conditions, edge and end distances, angle of load to the grain of the timber, and minimum timber thickness. The application of the load and the location for deformation measurements should be determined with reference to the specific situation under investigation.*

NOTE 2 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.

NOTE 3 Eccentricities not inherent in the design or resulting from actual service conditions and in advert restraints should be avoided.

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

(a) The loaded end surfaces of the specimen shall be essentially plane, square to the faces, and parallel.

(b) The loading surfaces of the testing machine shall, if fixed, be parallel across the loaded surfaces of the joint assembly.

NOTE These requirements are intended to ensure that the applied load is axial to the test specimen. For some testing machines the use of a spherical bearing block is necessary. The sample should be centred to avoid unbalance loading.

For specimens tested in tension, the following requirements shall apply:

(a) Timber members forming test specimen shall be extended beyond the intended specimen dimensions to allow for the attachment of suitable loading fixtures.

(b) The loading fixtures shall be designed so as not to influence the performance of the specimen and, where appropriate, shall be self-aligning to ensure that the applied load is axial to the test specimen.

(iii) Evaluation procedure

The evaluation shall be in accordance with Section 4.

(iv) Test report

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.

NOTE For timber connections, the sampling should ensure that the timber densities of the samples are appropriate for the reference population defined by the joint group or tooth group.

2.2 Sample method and size

The sampling method shall produce a sample that is representative of the reference population. It shall 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.

Where tests conducted are for failure in the timber, a minimum of 10 test values (i.e., $n = 10$) shall be used for a test series.

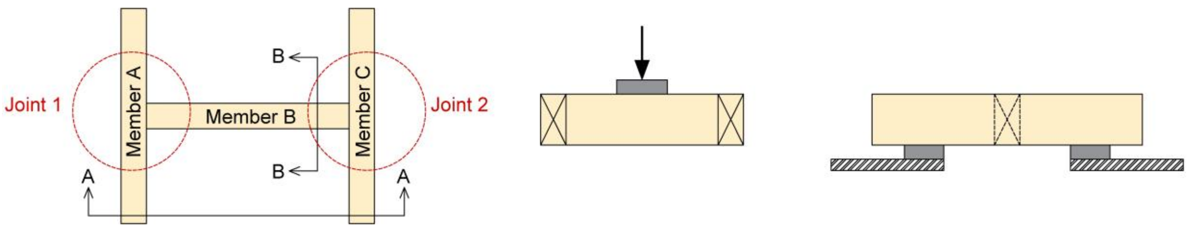
Where tests conducted are for failure in the metal, a minimum of five test values (i.e., $n = 5$) shall be used for a test series.

Each test specimen will result in one test value, except for Type H configuration for Category D fasteners, where one test specimen can result in a maximum of two test values.

NOTE For Category D fasteners, testing can be done using a symmetrical setup, such as a H-setup shown in Figure 3, where it is recommended that the difference in the density of timber Member A and Member C 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.

For the calculation of characteristic strength, all tests of the series must have the same failure mode. Failure mode for each test shall be recorded.

NOTE If a test differs in failure mode it is considered a rogue and another test will be required in its place.



Plan view Section A-A Section B-B

Figure 3 H-type assembly for test specimen, maximum sample size from a single test is two (n=2)

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.

NOTE The above includes any modification to the fastener's structural profile and material properties and may influence connection 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. See Section 1.6 for the assignment of joint group and tooth group.

NOTE 1 For sawn timber of a required species, a random selection of members from a sufficiently large parcel, or preferably from multiple parcels, is generally considered to be representative.

NOTE 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.

(iii) Where possible, each test specimen with sawn timber shall be cut from one stick of timber, such that the densities of each piece of timber in the test specimen are closely matched.

NOTE The orientation of growth rings in the members (e.g. quarter-sawn or back-sawn) is not considered significant, unless it is an attribute requiring 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; and
(iv) The details of the fastener(s) including edge and end distances, and spacings.
(v) The application of the load and restraint conditions.

NOTE As each type of test is designed to investigate a failure mode, the design of the test assembly should 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.

(i) For the **timber component**:
 (a) Timber product standard and/or specification;
 (b) Species or species group;
 (c) Density and designated joint group or tooth group;
 (d) Designated grade;
 (e) Size range of the product;
 (f) Moisture content;
 (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.

(ii) 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 (e.g., for the metal connector plates whether they are 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 and Category D fasteners when used with timber members to form a structural connection. The aim of the tests is 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 1.5.

The general principles of the test program shall be in accordance with Section 1.7.

3.2 Test specimens

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

3.3 Test setup for Category C fasteners

For Category C fasteners the following shall be considered:

(i) Failure in the timber: the shear (lateral) resistance of metal connector plate per tooth; and

(ii) Failure in the metal: the resistance of metal connector plate under tension and shear forces.

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

3.3.1 Failure in timber

The method of testing for determining the shear (lateral) resistance of the metal connector plate per tooth, shall include:

(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 4. 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

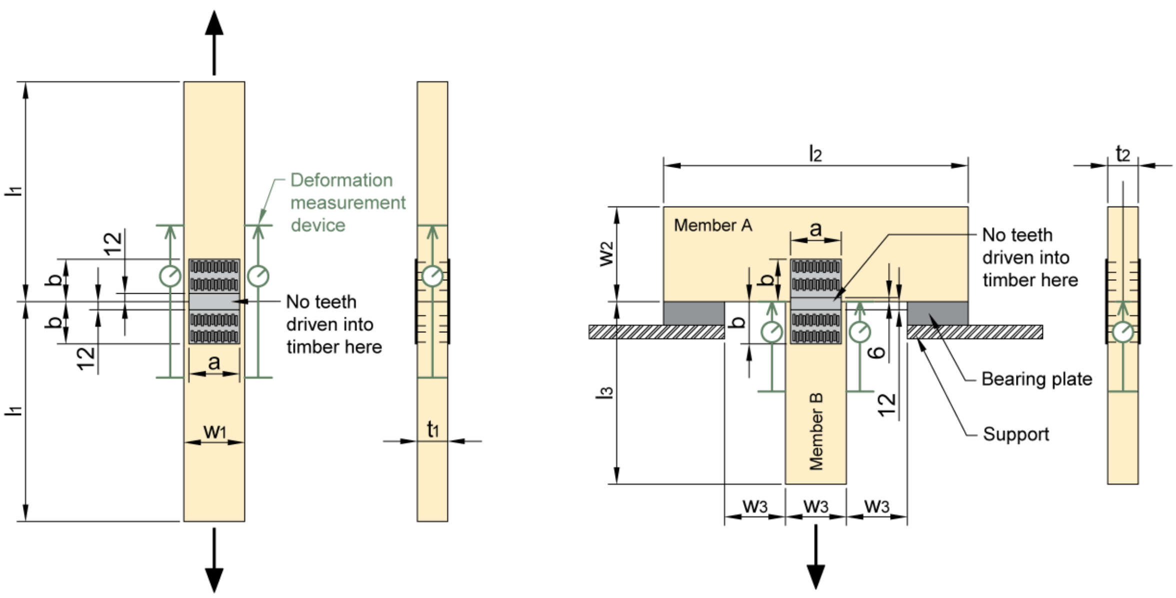
- l_2 = not less than the greater of 450 mm and 5a
- l_3 = not less than 3w_3
- $a, b, w_2, w_3\ and\ t_2$ = as specified by the manufacturer

(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; and
  (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 shall be close to each other but not compressed.



(a) Parallel Type (b) Perpendicular Type

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

(i) Using a test specimen as shown in Figure 5, 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) The preparation of at least five specimens, with metal connector plates selected at random as for the joint tests for failure in timber.

NOTE 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.

NOTE 2 Reference may be made to AS 1391 for additional details on the tensile testing of metals, if required.

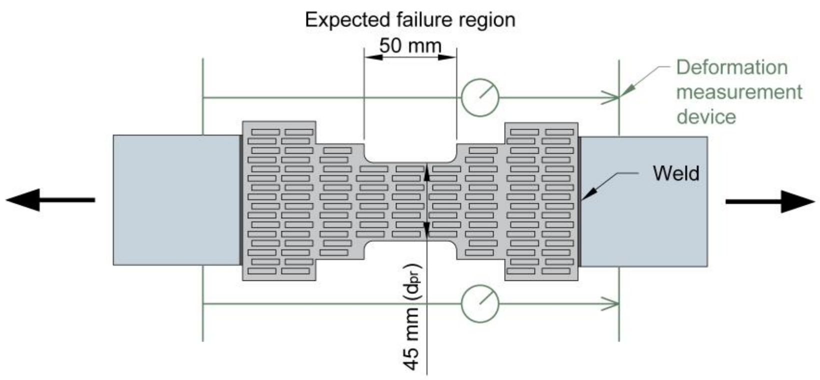


Figure 5 Test specimen configuration for the tensile resistance of the metal connector plate of Category C fasteners

3.3.2.2 Shear strength of the plate

The method of testing to determine the shear resistance of the metal connector plate shall include:

(i) Using the relevant test specimens as shown Figure 6. 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 shall 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 dimensions of the members are provided in Table 2. The width of the metal plate is w_p.

(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 shall be considered: $0°, 30°, 90°, 120°, \text{and } 150°$. 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 $90°$, the plates shall be positioned so that the axial component of the force in the plates is tensile. For angles greater than $90°$, the plates shall 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. The plate may be clamped or fastened at least 50 mm away from the joint to prevent withdrawal.

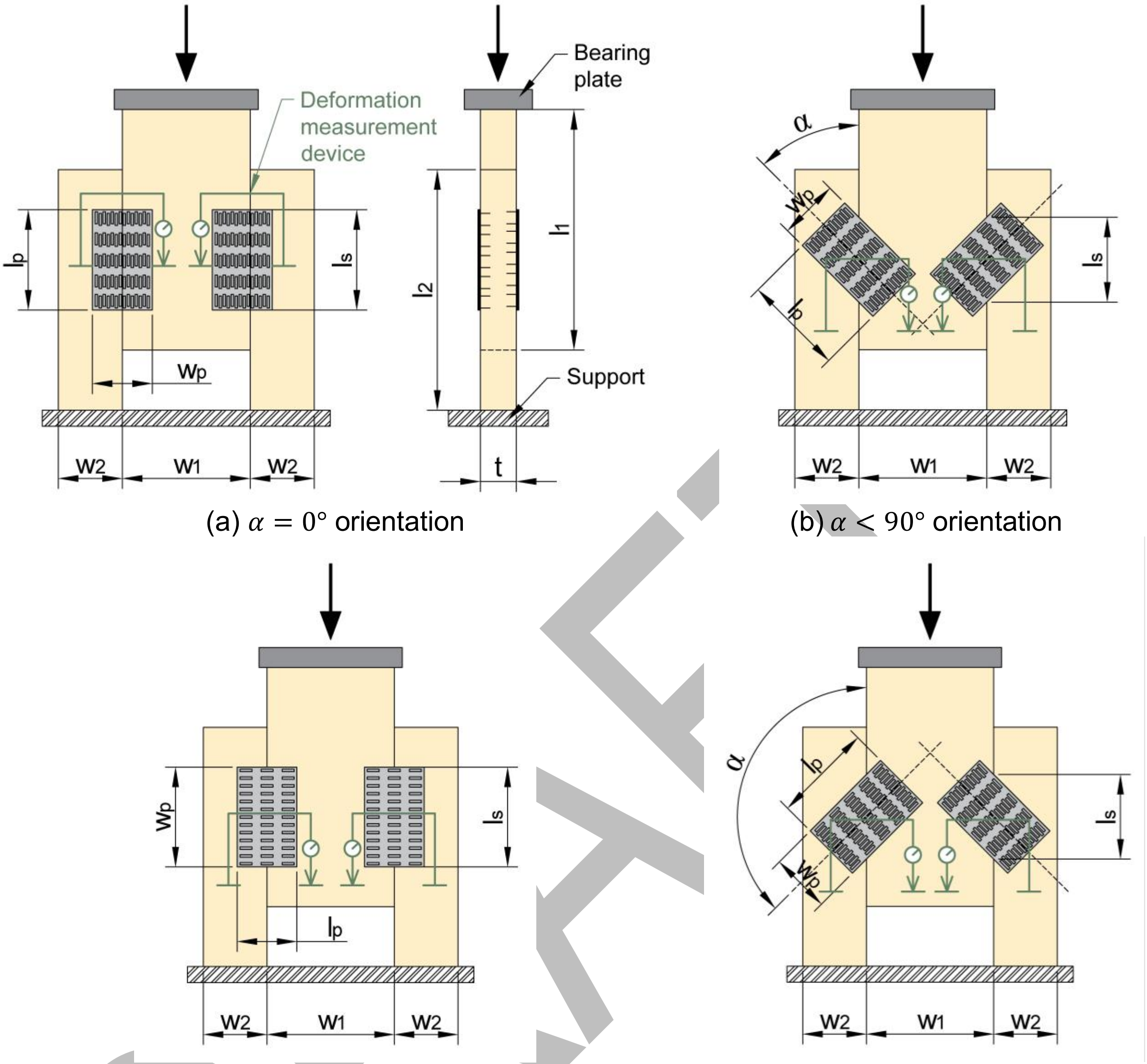
(v) The metal connector plate shall be embedded into the timber without removing any teeth.

(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 to 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 shall be checked that the product $w_1 \times t$ is not less than P/f_c, where P is the expected maximum load in newtons and f_c is the compressive strength of timber.

Table 2 Member dimensions for shear strength of metal connector plates

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



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

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

Figure 6 Test specimen configuration for the shear resistance of the metal connector plate of Category C fasteners

3.4 Test setup for Category D fasteners

For Category D fasteners the following shall be considered:

(i) Failure in the timber: the shear (lateral) resistance of the fastener governed by failure in the timber, and

(ii) Failure in the metal: the shear (lateral) resistance of the fastener governed by failure in the metal.

3.4.1 Failure in timber

The method of testing for determining the shear (lateral) resistance of Category D fasteners for when the failure is in the timber shall include:

(i) Adoption of suitable specimen configuration. One or more of the three specimen configurations, Type X, Type T, and Type H, as shown in Figure 7 shall be adopted. The member dimensions and the fastener locations shall be as follows:

(a) Type X (Figure 7a)
- l_1 and l_2 = not less than $3w_1$ and $3w_2$, respectively
- w_1, w_2, t_1 and t_2 = as specified by the manufacturer

(b) Type T (Figure 7b)
- l_1 = not less than $3w_1$
- l_2 = not less than greater of 225 mm and $3w_1$
- w_1, t_1 and t_2 = as specified by the manufacturer

(c) Type H (Figure 7c and d)
- l_1 and l_2 = not less than $3w_1$
- w_1, t_1 and t_2 = as specified by the manufacturer

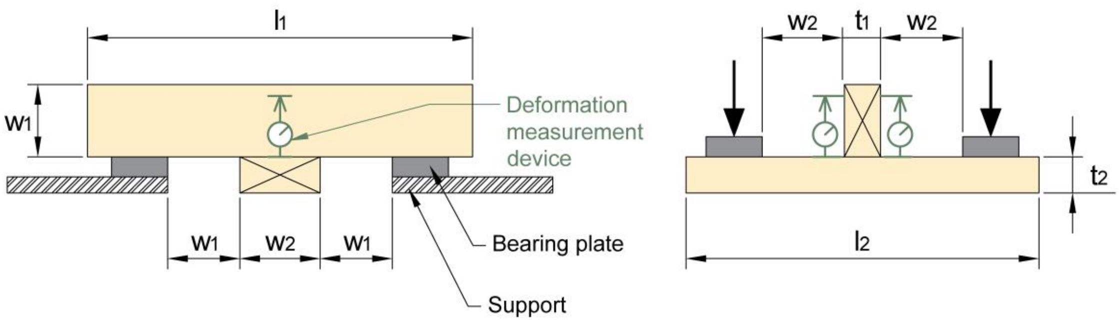
(ii) If exploratory tests indicate that the direction of loading affects the performance of the connection, then two series of tests shall be performed: one series for specimens tested in compression and another one for specimens tested in tension.

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

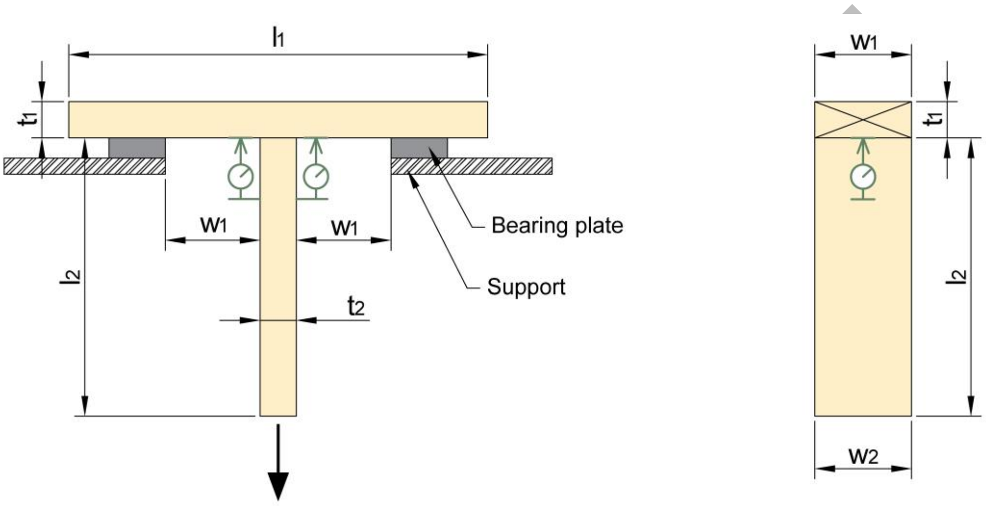
(iii) The metal fasteners (such as nails, screws, bolts) used to attach the pre-formed metal component shall be of a type, gauge, and length specified by the manufacturer.

(iv) Each joint shall be tested, as appropriate, in tension and/or compression using a testing machine of suitable capacity. Supports and/or suitably designed saddles shall be provided to ensure that the joint is tested in the intended manner.

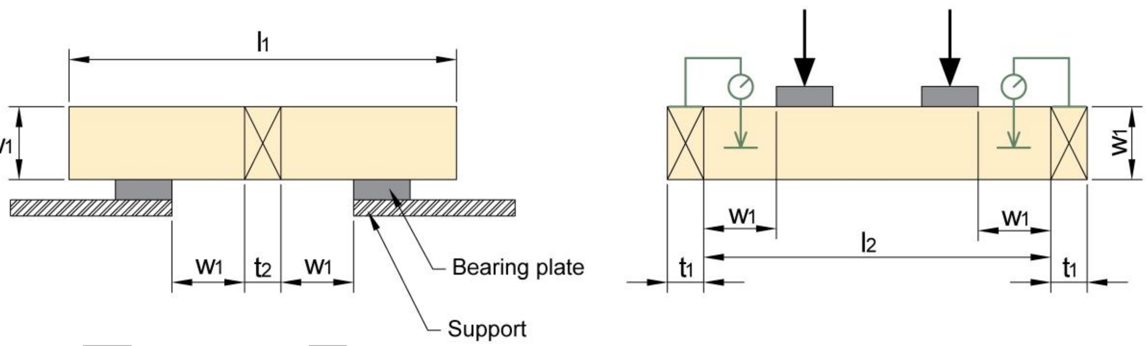
(v) All points of load application and support shall be located at a horizontal distance equal to the member width (w), measured from the junction of the two members joined by the fastener/s to be tested. Where bearing plates are used at the point of load application to distribute the load and prevent local failure, the horizontal distance from the edge of the bearing plate nearest to the joint shall be equal to the member width.



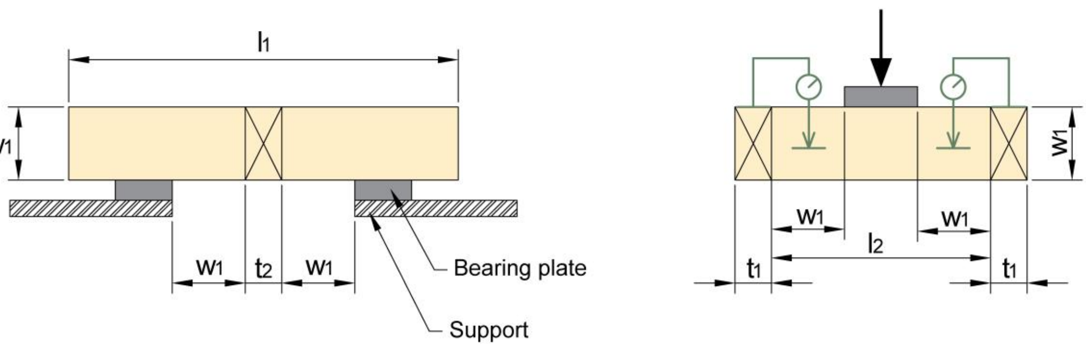
(a) Type X configuration



(b) Type T configuration



(c) Type H configuration with two-point loads



(d) Type H configuration with one-point load

Figure 7 Various test specimen configurations for determining the shear resistance of Category D fasteners

3.4.2 Failure in metal

The method of testing for determining the shear (lateral) resistance of Category D fasteners for when the failure is in the metal shall follow Section 3.4.1, with modifications to ensure metal failure.

NOTE Measures to achieve this may include the use of high-density timber members or steel members.

3.5 Application of load

The joints shall be tested in tension and/or in compression, 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 shall 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 shall be applied until a reduction of 30% of the maximum load is observed.

3.5.1 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.

NOTE 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 maximum 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.

NOTE 2 For connections typically used in residential construction, a crosshead movement rate of 1.25 mm +/- 25% per minute for Category C fasteners, and 0.06 mm +/- 25% per minute for Category D fasteners, may be appropriate for failure in timber. These rates may be adopted where the maximum load, P_{max}, is reached within approximately 5 to 10 minutes.

NOTE 3 Once the maximum load is reached, the load rate can be increased for ductile specimens.

3.5.2 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.

NOTE For connections typically used in residential construction, a crosshead movement rate of 0.3 mm +/- 10% per minute may be appropriate for failure in metal. This rate may be adopted where the maximum load, P_{max}, is reached within approximately 1 to 10 minutes.

3.6 Measurement of deformation

When deformation limits or slip criteria are critical to performance, and the stiffness of the connection is to be calculated accurately, the deformation (or slip) of the connection shall be continuously measured using suitable displacement measurement devices.

Two displacement measurement devices shall be used to measure the relative displacement between the connected timber members. The displacement measurement devices shall be attached such that other sources of deformation which are not related to the connection are minimised or avoided. Examples on correct positioning of the measurement devices are provided in Figure 4 and Figure 7. The deformation or slip of the connection shall be taken as the average of the displacement measured by the two devices.

NOTE The displacement provided by testing machines does not accurately capture the relative displacement between the connected timber members, with the discrepancy increasing as the stiffness of the connection increases. In some configurations and cases of connections with low stiffness, the displacement provided by the testing machine can be used as the connection deformation. However, preliminary tests should be performed to ensure that the displacement of the testing machine matches the readings provided by the displacement devices. This approach is typically only applicable to certain Category C connections. When deformation limits or slip criteria are not critical to performance, then the deformation provided by the testing machine can be used as an indication of the connection deformation.

3.7 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 where deformation limits or slip criteria are critical to performance.

3.7.1 Failure in timber

For failure in timber, the ultimate resistance shall be determined from test results in accordance with Section 4.2.1.

NOTE 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.*

3.7.2 Failure in metal

For failure in metal, the ultimate resistance shall be determined from the test results in accordance with Section 4.3.1.

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

Section 4 Evaluation Procedure

4.1 General

This section describes the procedures for evaluating test results for Category C and Category D fasteners for:

(i) Failure in timber, see Section 4.2; and

(ii) Failure in metal, see Section 4.3.

4.2 Failure in timber

This section describes the evaluation procedure for failure in timber and shall be used to determine the:

(i) Shear (lateral) resistance of metal connector plate per tooth from test results for Category C fasteners; and

(ii) Shear (lateral) resistance of the Category D fastener from test results.

4.2.1 Ultimate resistance and corresponding deformation from test results

Where deformation limits and slip criteria are not critical to performance of the connection, the test ultimate load resistance (P_t), shall be taken as the observed maximum load (P_{max}).

Where deformation limits or slip criteria are critical to performance of the connection, the deformation shall be measured as per Section 3.6. The following procedure shall be adopted to determine the test ultimate load resistance and the corresponding deformation:

(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 $\delta_t = \delta_{acc}$

NOTE 1 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 should be taken as $P_{u/sl}$ or the test should be repeated. See Figure 8 for examples of determining the test load capacity from the load-deformation curve.

NOTE 2 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 BS EN 26891 (ISO 6891) 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 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.

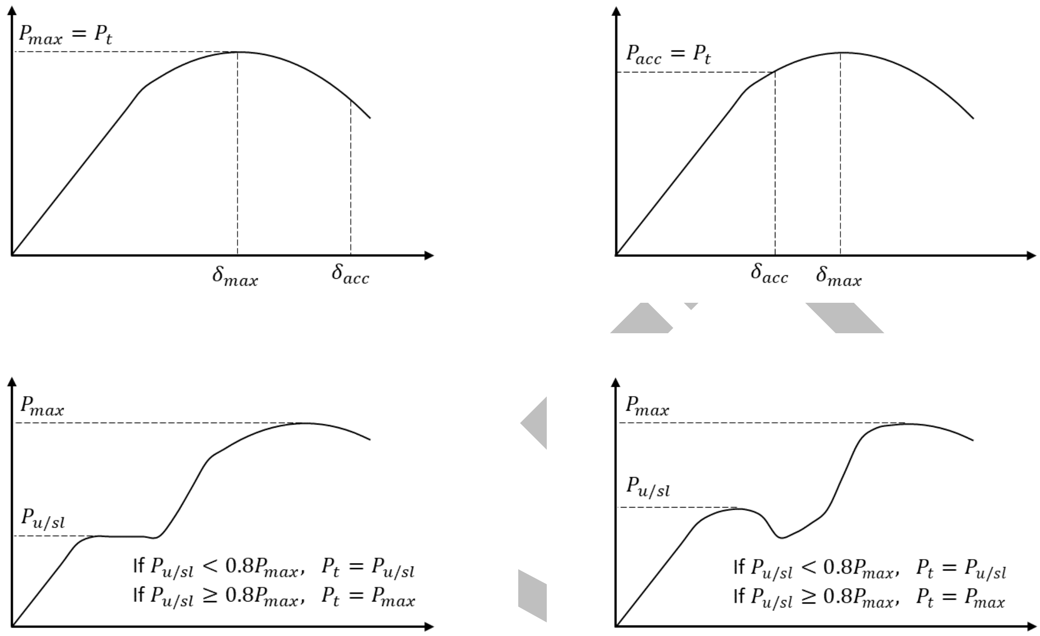


Figure 8: Test load capacity from the load-deformation curve

4.2.2 Correction of test results for timber density for Category D fasteners

Where applicable, the test results shall be corrected for timber density using Section 4.2.2 for Category D fasteners for which nails or screws connect the pre-formed metal component to the timber. The following shall be considered when correcting for timber density:

(i) 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 is determined from testing or calculations using engineering principles.

(ii) Correction for timber density or extrapolation of test results for other reference populations using timber density shall only be made for failure modes which are dependent on timber density.

(iii) Correction shall not apply if perpendicular to the grain tension failure governs 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 ultimate load resistance from the test data for test value i corrected to refer to $\rho_{m,ref}$

$P_{t,i}$ = ultimate load 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. For JD groups $\rho_{m,ref}$ shall be taken as the group average density in Table 1

$\rho_{m,test}$ = 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 $1.10 < \frac{\rho_{m,ref}}{\rho_{m,test}} \leq 1.40$

x = 2.0 if $0.70 \leq \frac{\rho_{m,ref}}{\rho_{m,test}} < 0.90$

NOTE 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 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.

NOTE 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 0.70 or higher than 1.40. These limits approximately correspond to one joint group above or below the joint group which has been tested based on the mean density of the timber samples.

4.2.3 Coefficient of variation of the reference population

The coefficient of variation for the reference population, V_p, shall be assessed with reference to a failure mode to determine the characteristic value of the ultimate resistance from the test results.

For Category C fasteners, V_p shall be taken as follows, such that both (i) and (ii) are satisfied:

(i) It shall not be less than 0.20, unless it is demonstrated, based on a comprehensive test program, that a lower value within the range of 0.10 to 0.20 is appropriate. A comprehensive test program shall include testing of the Category C fastener across multiple timber species and grades, with not less than 100 specimens for each species and grade; and

(ii) It shall not be less than the coefficient of variation of the test results, V_t, determined in accordance with Eq. 3.

For Category D fasteners, V_p shall be taken as follows, such that both (i) and (ii) are satisfied:

(i) It shall not be less than 0.20; and

(ii) It shall not be less than the coefficient of variation of the test results, V_t, determined in accordance with Eq. 3.

$$V_t = \frac{sample\ standard\ deviation\ of\ the\ test\ results}{mean\ of\ the\ test\ results} \qquad \text{Eq. 3}$$

The procedure for calculating the characteristic value in Section 4.2.4 shall be applicable where V_p is less than or equal to 0.40.

NOTE When comprehensive data are available, the coefficient of variation of the reference population may be approximated using: $V_p = \sqrt{{V_a}^2 + {V_m}^2 + {V_f}^2}$, where V_a is the 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 is the coefficient of variation as the result of material variation (dependent on the mode of failure and the properties of the timber), and V_f is the coefficient of variation as the result of fabrication variation.

4.2.4 Characteristic value from test results

The general equation for calculating the characteristic value of the ultimate resistance of a connection governed by failure in timber is provided in Eq. 4, where:

(i) $\overline{P}_t$ is mean value of the ultimate load resistance from the test data;

(ii) k_t is the sampling factor corresponding to a 5-percentile value at 75% confidence, assuming a lognormal distribution, as given in Table 3. It is a function of the number of test values (n) and the coefficient of variation of the reference population of the connection (V_p). Linear interpolation of k_t between tabulated values is permitted;

(iii) $\overline{P}_t/k_t$ represents the statistical characteristic value, corresponding to the 5-percentile value at 75% confidence based on a lognormal distribution;

(iv) a_v is the modification factor for variation. Where applicable, it shall be used to reduce the statistical characteristic value ($\overline{P}_t/k_t$) in order to maintain the level of structural reliability adopted in the derivation of design strength in AS 1720.1. The factor a_v shall not exceed 1.0 and shall:

(a) Be determined as $a_v = 1 - (V_p - 0.2)^{0.7} \leq 1.0$, when:

- $0.2 < V_p \leq 0.4$; and
- the capacity factors in AS 1720.1 for multi-toothed nailplates (Category C), nails, screws, and bolts and coach screws of M16 diameter and smaller (corresponding to the fasteners used to attach the pre-formed metal component to the timber forming the Category D fastener) are to be adopted.

(b) Be taken as 1.0 for when the capacity factors in AS 1720.1 for bolts and coach screws with diameters greater than M16 are to be adopted.

NOTE The structural reliability of the characteristic values defined in this document, in combination with the capacity factors in AS 1720.1, has been assessed in accordance with Verification Method BV1 in the National Construction Code (NCC, 2022). The factor a_v should be applied where $0.2 < V_p \leq 0.4$ and the capacity factors specified in AS 1720.1 for multi-toothed nailplates, nails, screws, and bolts and coach screws of M16 diameter and smaller are adopted. In these cases, the application of a_v reduces the statistical *characteristic value to maintain the level of structural reliability adopted in the derivation of design strengths in AS 1720.1. The factor a_v is not required for bolts and coach screws with diameters greater than M16, as the corresponding capacity factors in AS 1720.1 incorporate this effect.*

The application of Eq. 4 for specific fastener categories shall be determined in accordance with:

(i) Section 4.2.4.1 for ultimate shear (lateral) resistance of the metal connector plate per tooth for Category C fasteners, and

(ii) Section 4.2.4.2 for ultimate shear (lateral) resistance of the Category D fasteners.

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

Where

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

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

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

n = number of test values.

a_v = modification factor for variation.

k_t = sampling factor for timber failure, provided in Table 3.

V_p = coefficient of variation of the reference population of the connection, see Section 4.2.3.

Table 3 Sampling factor for failure in timber, k_t

No of tests values, n	Sampling factor (k_t) for the coefficient of variation of connection reference population V_p			
	0.1	**0.2**	**0.3**	**0.4**
10	1.21	1.47	1.80	2.19
20	1.20	1.45	1.77	2.15
50	1.19	1.44	1.74	2.11
100	1.18	1.41	1.69	2.03

4.2.4.1 Ultimate shear resistance of plate per tooth for Category C fasteners (failure in timber)

The characteristic ultimate shear (lateral) resistance of the metal connector plate per tooth shall be calculated from the test results using Eq. 5.

$$R_k = \frac{\overline{P}_t a_v}{k_t N} \qquad \text{Eq. 5}$$

Where

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

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

4.2.4.2 Ultimate shear resistance for Category D fasteners (failure in timber)

The characteristic ultimate shear (lateral) resistance of the Category D fastener governed by failure in the timber shall be calculated from the test results using Eq. 6.

$$R_k = \frac{\overline{P}_t a_v}{k_t} \qquad \text{Eq. 6}$$

Where

$\overline{P}_t$ = mean value of the strength resistance from the test data which has been corrected for density when necessary.

4.2.5 Capacity factor

The suitable capacity factors (ϕ) in AS 1720.1 shall be adopted for determining the design resistance of Category C and Category D fasteners governed by failure in timber.

4.2.6 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 ($\overline{\delta}_t$) shall be calculated using Eq. 7.

$$\overline{\delta}_t = \sum_{i=1}^{n} \frac{\delta_{t,i}}{n} \qquad \text{Eq. 7}$$

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

4.3 Failure in metal

This section describes the evaluation procedure for failure in metal and shall be used to determine the:

(i) Tension resistance of metal connector plate from test results for Category C fasteners,

(ii) Shear (lateral) resistance of metal connector plate from test results for Category C fasteners,

(iii) Shear (lateral) resistance of the pre-formed metal component of the Category D fastener from test results.

The evaluation procedure specified in this section has been developed for cold-formed steel components. For other metallic materials, the evaluation shall be conducted in accordance with the relevant design standards.

4.3.1 Ultimate resistance from test results

The ultimate load 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.

NOTE: ISO 8969 suggests for Category C fasteners where the plate is subjected to shear, the strength may be taken as the highest load reached, with an upper limit of the load at a slip of six times the plate thickness between the joint members, if the curve is still rising at this displacement.

4.3.2 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 to determine the characteristic value of the ultimate resistance from the test results.

V_p shall be taken as follows, such that both (i) and (ii) are satisfied:

(i) It shall not be less than 0.10; and

(ii) It shall not be less than the coefficient of variation of the test results, V_t, determined in accordance with Eq. 8.

$$V_t = \frac{sample\ standard\ deviation\ of\ the\ test\ results}{mean\ of\ the\ test\ results} \qquad \text{Eq. 8}$$

The procedure for calculating the characteristic value in Section 4.3.3 shall be applicable where V_p is less than or equal to 0.30.

NOTE When comprehensive data are available, the coefficient of variation of the reference population may be approximated using: $V_p = \sqrt{{V_a}^2 + {V_m}^2 + {V_f}^2}$, where V_a is the 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 is the coefficient of variation as the result of material variation (dependent on the mode of failure and the properties of the metal), and V_f is the coefficient of variation as the result of fabrication variation.

4.3.3 Characteristic value from test results

The general equation for calculating the characteristic value of the ultimate resistance of a connection governed by failure in metal is provided in Eq. 9, where:

(i) $\overline{P_t}$ is mean value of the ultimate load resistance from the test data;

(ii) k_m is the sampling factor corresponding to a 5-percentile value at 99% confidence, assuming a Weibull distribution, as given in Table 4. It is a function of the number of test values (n) and the coefficient of variation of the reference population of the connection (V_p). Linear interpolation of k_m between tabulated values is permitted.

(iii) $\overline{P_t}/k_m$ represents the statistical characteristic value, corresponding to the 5-percentile value at 99% confidence based on a Weibull distribution.

The application of Eq. 9 for specific fastener categories shall be determined in accordance with:

(i) Section 4.3.3.1 for ultimate tensile strength of the plate for Category C fasteners,

(ii) Section 4.3.3.2 for ultimate shear strength of the plate for Category C fasteners, and

(iii) Section 4.3.3.3 for ultimate shear strength of the pre-formed metal component for Category D fasteners

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, with modifications made to suit Categories C and D fasteners. The determination of the characteristic value follows these standards when the mean of the test results is used.

NOTE NASH Standard Residential and Low-rise Steel Framing, Part 1: Design Criteria and AS/NZS 4600 allow the characteristic capacity to be determined from test results using either the mean value divided by a sampling factor or the minimum value divided by a corresponding sampling factor. In this Standard, the characteristic value is determined using the mean of the test results, as this approach provides greater consistency.

$$R_k = \frac{\overline{P}_t}{k_m} \qquad \text{Eq. 9}$$

Where

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

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

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

n = number of test values.

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

V_p = coefficient of variation of the reference population of the connection, see Section 4.3.2.

Table 4 Sampling factor for metal failure, k_m, for use with mean value of test results

No of test values, n	Sampling factor k_t for the coefficient of variation of connection reference population V_p				
	0.1	**0.15**	**0.2**	**0.25**	**0.30**
5	1.34	1.57	1.85	2.20	2.62
10	1.31	1.51	1.77	2.07	2.45
20	1.28	1.47	1.70	1.98	2.32
50	1.27	1.45	1.67	1.92	2.24
100	1.25	1.42	1.62	1.86	2.15

4.3.3.1 Ultimate tensile strength of the plate for Category C fasteners (failure in metal)

The characteristic ultimate tensile resistance per unit width of the metal connector plate for Category C fasteners shall be calculated using Eq. 10.

$$R_k = \frac{\overline{P}_t}{k_m d_{pr}} \qquad \text{Eq. 10}$$

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.

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

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

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

4.3.3.2 Ultimate shear strength of the plate for Category C fasteners (failure in metal)

The characteristic ultimate shear strength per unit length of the metal connector plate for Category C fasteners shall be calculated using Eq. 11.

$$R_k = \frac{\overline{P}_t}{k_m l_s} \qquad \text{Eq. 11}$$

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.

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

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

l_s = calculated shear length of the metal connector plate (see Figure 6)

4.3.3.3 Ultimate shear strength of the pre-formed metal component for Category D fasteners (failure in metal)

The characteristic ultimate shear strength for the pre-formed metal component for Category D fasteners shall be calculated using Eq. 12.

$$R_k = \frac{\overline{P}_t}{k_m} \qquad \text{Eq. 12}$$

Where

$\overline{P}_t$ = mean value of the ultimate strength resistance from test data for one pre-formed metal component

4.3.4 Capacity factor

For prototype testing of cold-formed steal, NASH Standard and AS/NZS 4600 specify a capacity factor (ϕ) of 1.0.

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 load resistance, including 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 load 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 – Determination of yield strength and deformation for failure in metal (Informative)

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.

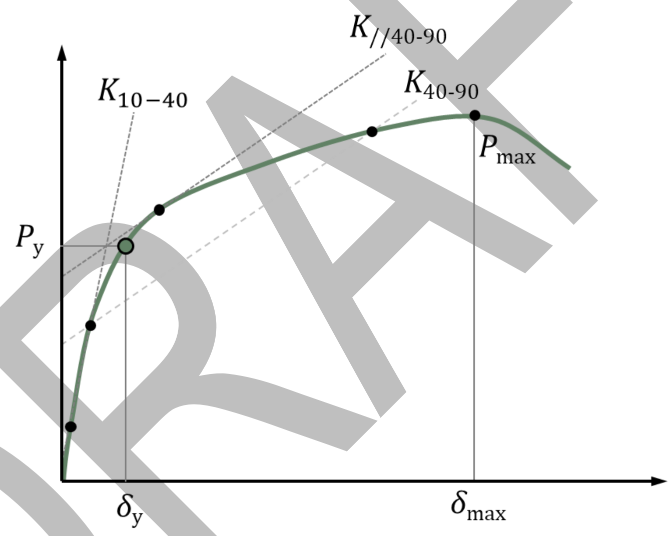


Figure A1 Method for determining the yield point on a load-deformation curve

Bibliography

Amirsardari A, Lee J, Pham L, & Gad E. (2023). *Evaluating the performance of Category D timber connections.* Paper presented at the 26th Australasian Conference on Mechanics of Structures and Materials (ACMSM26), Auckland, New Zealand: Lecture Notes in Civil Engineering, Springer Nature.

Amirsardari, A., Lee, J., Gad, E., & Pham, L. (2023). Review of timber connection design in Australia. *Australian Journal of Structural Engineering*, 206-216. doi:10.1080/13287982.2023.2213499

ANSI/TPI (American National Standards Institute and Truss Plate Institute). (2022). *ANSI/TPI 1-2022: National design standard for metal plate connected wood truss construction*. MD, USA: Truss Plate Institute, Inc

ASTM International. *ASTM D7147 Standard specification for testing and establishing allowable loads of joist hangers*. West Conshohocken, PA: ASTM International

Australian Building Codes Board (ABCB). (2022). *National Construction Code: Volume One - Building Code of Australia*. Canberra, Australia: Australian Building Codes Board, Commonwealth of Australia and the States and Territories of Australia

Australian Engineered Fasteners and Anchor Council (AEFAC). (2022). *AEFAC TFTN01: Joint groups for timber fasteners and connectors*. AEFAC Retrieved from https://www.aefac.org.au/documents/TN/AEFAC-TFTN01-Joint-groups.pdf

British Standards Institution (BSI).. *BS EN 2689, ISO 6891 - Timber structures - Joints made with mechanical fasteners - General principles for the determination of strength and deformation characteristics*.

Forest & Wood Products Australia - *Industry standard – Methods of test for mechanical fasteners and connectors Part 1: Category A&B Fasteners, Project Number: PNB460-1718.*

Hubbard, C., & Salem, O. (2024). A new moment-resisting glulam beam-end connection utilizing mechanically fastened steel rods - An experimental study. *Applied mechanics, 5*, 260-279. doi:10.3390/applmech5020016

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

Wang, C.-H., & Pham, L. (2012). Sampling factors for prototype testing of structures. *Australian Journal of Structural Engineering, 12*(2), 119-126. doi:10.7158/13287982.2011.11465084

FWPA Standards Writing Committee

The FWPA Standard T02 Methods of test for mechanical fasteners and connectors Part 2: Category C&D Fasteners was prepared by the Standards Writing Committee with contributions from:

Australian Engineered Fasteners and Anchors Council (AEFAC)

Griffith University

MiTek Australia

Multinail Pty. Ltd.

Pryda

Simpson Strong-Tie Company Inc.

Swinburne University of Technology

TGA Engineers

Timber Queensland Ltd