FWPA Standard

T01

Methods of test for mechanical fasteners and connectors

Part 1: Category A & B Fasteners

2026

Edition 1

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Forest & Wood Products Australia

Methods of test for mechanical fasteners and connectors
Part 1: Category A & B Fasteners

FWPA Standard T01

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T01 Methods of test for mechanical fasteners and connectors

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Amendment Schedule

Edition	Date	Description
1.0	15 May 2026	First Edition

Preface

AS 1649 (Timber - Methods of test for mechanical fasteners and connectors - Basic working loads and characteristic strengths), was published in 2001 as a “soft conversion” from the previous 1998 edition to a Limit State format consistent with AS 1720.1 (1997). The test methods contained in AS 1649 are essentially the same as those documented in the first version, published as AS A188 in 1972.

This FWPA Standard has been developed as an Industry Standard by ARC Advanced Timber Hub, University of Queensland in collaboration with Engineered Wood Products Association of Australasia (EWPAA) and funded by FWPA as an alternative to using AS 1649 (2025) for testing and determination of Characteristic Capacities for specific types of commonly used connections, for sawn timber and all engineered wood products. This includes Category A (nails, staples or screws) and Category B (bolts and dowels) laterally loaded (Type 1) fasteners and connection assemblies, for design of joints in timber structures in accordance with AS 1720.1.

The design capacities evaluated in accordance with this Industry Standard may be used for designs in accordance with AS 1720.1 through the assignment of either:

a) A characteristic strength value for a specific connection type or system that is not described in AS 1720.1; or
b) A nominated Joint Group defined in this Industry Standard for joint types that are described in AS 1720.1.

AS1720.1 design values are based on empirical test data that aligns with the compression strength at the proportional limit and/or the yield of the fastener for laterally loaded Category A and B fasteners. The proportional limit is defined as the point where the load versus deformation is no longer linear. The proposed method defines the yield point as the failure criteria, which will be higher than the proportional limit.

Requirements for the testing and characterisation of Category A & B fasteners loaded in withdrawal (Type 2) and Category A inclined screws (subject to both axial and lateral loads) have been revised and are included in this Industry Standard.

Testing and characterisation of Category C and D connections (nailplates and brackets) require a different philosophy than that relevant for Category A and B connections. This is outside the scope of this document. “Industry Standard - Methods of test for mechanical fasteners and connectors; Part 2: Category C & D Fasteners” is under preparation.

A comprehensive review of relevant international research reports, ISO, EN and ASTM Standards has been undertaken prior to the development of this document, and a number of these publications are reference documents for this Standard. As such, this document reflects international requirements and procedures for joints made with mechanical fasteners. The testing procedures have been developed to obtain information about their strength, stiffness, ductility and deformation (slip) characteristics.

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 Standard describes the general principles for the determination of the strength, stiffness, ductility and deformation (slip) characteristics of joints made from sawn timber and engineered wood products, (e.g. glulam, plywood, Laminated Veneer Lumber (LVL) and Cross Laminated Timber (CLT)) made with laterally loaded or axially loaded mechanical fasteners, including identification of failure modes. It specifies methods for testing individual fasteners and connection assemblies and sets out procedures for the determination of characteristic design information applicable to timber joints in which the fasteners are incorporated.

The principles in this Standard can also be used for the testing of other joints, including two-member joints.

The Scope of this Standard is limited to structural timber products and connector types that represent the majority currently used in Australia comprising 3-member connections (Note 1). As such, the Scope of this Standard is limited to connector types referred to in AS1649 as Category A (nails, staples or screws) and Category B (bolts and dowels) Fasteners; specifically nails, screws, staples, bolts and dowels, manufactured from steel to a relevant standard.

NOTE 1 Testing of two-member connections is outside the scope of this Standard, as it will often result in out-of-plane and eccentric loading of fastener(s).

NOTE 2 Established joint groups exist for various timber species and can be found in AS 1720.1 and other standards. Species and materials not currently listed can generate joint group properties in a manner consistent with those already referenced in Australian Standards. Special consideration should be given to engineered wood products due to their unique properties.

NOTE 3: Whilst the Scope of this Standard is restricted to seasoned timber, the test procedures may also be applied to connection assemblies made from unseasoned or partially seasoned timber, noting that the sample size may need to be increased in order to derive characteristic properties from a statistically valid analysis of the test data.

1.2 Normative references

The following documents are referred to in this Standard:

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

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

AS/NZS 4063.2 Characterization of structural timber - Part 2: Determination of characteristic values

AS/NZS ISO 10984.1 Timber Structures – Dowel-type fasteners – Part 1: Determination of yield moment

ASTM D1761 Standard Test Methods for Mechanical Fasteners in Wood

ASTM D5764 Standard Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood- Based Products

ASTM F1575 Standard Test Method for Determining Bending Yield Moment of Nails

EN 383 Timber Structures - Test methods - Determination of embedment strength and foundation values for dowel type fasteners

EN 409 Timber structures - Test methods - Determination of the yield moment of dowel type fasteners

EN 12512 Timber structures - Test methods - Cyclic testing of joints made with mechanical fasteners

ISO 554 Standard atmospheres for conditioning and/or testing – Specifications

ISO 6891 Timber structures - Joints made with mechanical fasteners; General principles for the determination strength and deformation characteristics

ISO 12122-1 Structural Timber Products - Determination of characteristic values - Part 1: Basic Requirements

ISO 12122-6 Timber Structures - Determination of characteristic values - Part 6: Large Components and assemblies

ISO 21581 Timber structures - Static and cyclic lateral load test methods for shear walls

AEFAC Guide for testing & evaluation of timber connection Category D

1.3 Definitions

For the purpose of this Standard, the definitions below apply.

1.3.1 Characteristic Value: The value of a property taken to represent the property of a designated population using a process of sampling, testing of specimens, and analysis.

1.3.2 Characteristic value of mean-based property: Two alternative presentations of characteristic value for mean-based properties are possible:

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

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

1.3.3 Characteristic value of 5th percentile-based strength property: 5th percentile value with 75% confidence strength property obtained from results of tests on the defined product.

1.3.4 Connector: Used inter-changeably with the term fastener. The scope of this standard (Part 1) is limited to dowel-type fasteners, which includes screws, nails, staples, bolts and dowels.

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

1.3.6 Fastener: A unit fastening device, together with other components that may be required, that enables a sound structural joint to be made between two or more timber members, or between timber and members of other structural materials.

1.3.7 Joint: Used inter-changeably with the term connection.

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

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

1.3.10 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.

1.4 Notation

The following symbols are used in this Standard:

a_x	=	Centre to centre spacing between fasteners, edge or end distance (mm) Where x = 1, 2, 3, 4 or 5
D	=	Diameter (root diameter in the case of screws) of a fastener (mm)
E	=	Mean stiffness of connection from test data (N/mm)
E_k	=	Characteristic value for stiffness
E_m	=	Test mean value of stiffness
E_{05}	=	5th percentile value for stiffness of connection from test data (N/mm)
f_k	=	Characteristic capacity of a connection (N)
F_{est}	=	Estimated maximum load (kN)
F_{max}	=	Maximum load (kN)
F_{PL}	=	Load at proportional limit (kN)
F_{ult}	=	Ultimate load at failure (kN)
F_y	=	Load at yield (kN)
JD	=	Joint group for seasoned timber
k_m	=	Sampling factor for mean-based properties with 75% confidence
k_{mod}	=	Applicable modification factor as specified in AS1720.1
k_s	=	Sampling factor
k_z	=	Confidence coefficient for estimating the 5th percentile strength with 75% confidence
k_{05}	=	Ratio of Mean to 5-percentile
l	=	Member offset to permit relative deformation (mm)

l_1, l_2, l_3	=	Member offsets to permit relative deformation (mm) - perp. to grain test configuration
L	=	Length of a fastener (mm)
n	=	Sample size
l_p	=	Length of penetration of the fastener into the timber member (mm)
P	=	Applied load (kN) during testing
R_k	=	Characteristic value (kN)
R_m	=	Test mean value (kN)
t or t_1	=	Thickness of the timber members (mm)
t_2	=	Thickness of the timber side members (mm) - perp. to grain test configuration
V_R	=	Coefficient of variation of test data
V_t	=	Test coefficient of variation
w, w_1	=	Width of the timber members (mm)
w_2	=	Width of the timber side members (mm) - perp. to grain test configuration
Δ_{ult}	=	Deformation or slip at the Ultimate load F_{ult} (mm)
Δ_y	=	Deformation or slip at the yield load F_y (mm)
$\boldsymbol{\phi}$	=	capacity factors as given in AS1720.1
μ	=	Ductility ratio

The following symbols are specific to embedment test configurations noted in Figure 3.1a & 3.1b.

l_1, l_2, l_3 l_4, l_5	=	Dimensions for determination of yield moment of fasteners (AS/NZS ISO 10984.1)
$\phi\, d$	=	Diameter of fastener (AS/NZS ISO 10984.1) – This is noted as "*D*" in AS 1720.1
$F_1, F_2,$ F_3, F_4	=	Loads for determination of yield moment of fasteners (AS/NZS ISO 10984.1)

1.5 General Requirements for Fasteners and Timber

1.5.1 Fasteners

The fasteners selected for test purposes shall be representative of commercial production, manufactured in conformity with a relevant product Standard.

> *Commentary 1.5.1*
> *It is important to clearly and precisely specify the fasteners used in the tests, as small details (e.g. head, shank shape and size) may affect the performance of the connection. Provided the specific details of the fasteners, the type of timber product and the connection geometry is carefully documented, it is possible to use this Standard to test new fasteners in order to characterise the connection performance in the absence of relevant product standards.*

1.5.2 Timber and Engineered Wood Products

The timber and engineered wood products selected for test purposes shall comply with the following requirements:

(a) Quality: No significant strength reducing characteristics shall be present except small pin knots, if typical of the species.

(b) Species: When general design data is required, the species shall be chosen from those in common use as structural timbers. When establishing the properties of a fastener in a particular joint group, a species not representative of the ones commonly used in practice for the product shall not be selected. The species chosen shall be positively identified by its botanical name.

NOTE For example, the selection of a timber broadly classified as Victorian hardwood, which could be either a single species or a mixture of several species representing a relatively wide range of strength properties, would not be appropriate for establishing design values for a specific joint group.

> *Commentary 1.5.2*
> *Clause 1.10 specifies requirements for species suitable for tests for the determination of design properties for the joint strength groups provided in AS 1720.1.*

(c) Representation: The test sample shall be such that the specimens are representative of the material being sampled, which is described as the reference population (refer Clause 1.6).

(d) Moisture content: All timber and engineered wood products used in connections that are tested in accordance with this Standard, shall be in a seasoned condition (as defined in AS 1720.1).

(e) Density: Where possible, each test specimen shall be cut from one stick of timber, such that the densities of each piece of timber in the test specimen are matched, within 5% of one another.

NOTE The testing procedures presented in Section 2 are generally applicable to all timber members. However, the analysis of the results of testing timber products intended for use in either a partially seasoned or unseasoned condition is not specifically considered within the scope of this Standard and would need to consider the size and variability of the test sample.

1.6 Reference Population

The population to which the characteristic value applies shall be fully described. These include:

Timber

a) reference to the relevant product standard or specification;

b) species or species grouping;

c) density of the samples;

d) designation of grade of the product;

e) size or size range of the product;

f) moisture condition of the product;

g) treatment of the product;

h) period in which the product was manufactured.

Connections

i) material of the connecting components;

j) dimensions of the connecting components;

k) method of assembly (e.g. predrilling of holes)

l) dimensions of the assembly, in particular end distances, edge distances and connector spacings;

m) presence or exclusion of specified features (e.g. knots or finger joints) in or near the connection;

n) moisture exposure conditions (before and after specimen preparation);

o) moisture conditions when the specimen is installed and tested.

Where the densities of timber components comply with AS/NZS 1080.3, this can be declared as part of the reference population.

NOTE *An Informative commentary and guidance on defining a reference population can be found in Annex B of ISO 12122-1.*

> *Commentary 1.6*
> *The description should reference all of the attributes that may affect either the strength or stiffness and restrict the pieces to the grouping for which the characteristic value is required.*
> *The reference population should be a grouping from which it is possible to draw a representative sample, and on which it is possible to perform tests on specimens to characterise the required properties.*

1.7 Sampling

1.7.1 Sampling method

The sampling must ensure that the densities of all test specimens are appropriate for the targeted JD group.

The sampling method shall be documented.

> *Commentary 1.7.1*
> *The method should aim to produce a sample that is representative of the variants in the defined reference population that may affect the tested properties. The sampling should minimize selection bias and should be appropriate to the purpose of the characteristic value and the nature of the reference population.*
>
> *The documentation should include details of the steps taken to ensure that each of the variants listed in the population as described in Clause 1.6 is included in the representative sample. Where possible, the timber members in each connection assembly (joint) should be selected to have representative properties, particularly for density and moisture content.*

1.7.2 Sample size

A minimum of 10 joints for each test series shall be fabricated and tested using seasoned timber. for each test series when determining characteristic values for use in limit-state design (e.g. AS 1720.1).

Where results are intended to define a statistical distribution, at least 30 specimens shall be tested. Additional statistical guidance is provided in Informative Appendix A and in the notes below.

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

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

NOTE 3 Annex B of ISO 12122-1 gives some guidance on selecting sample size.

NOTE 4 For some populations, a number of different sub-groups within the population may need to be sampled (e.g. different cross-sectional sizes). In these cases, the size of each of the sub-groups may have to be sufficient to allow meaningful pooling of the results as indicated in Annex A of ISO 12122-1.

NOTE 5 In situations where full scale, large components or connection assemblies are to be tested, it is often not feasible to test more than 3 specimens. This creates a specific statistical issue, namely that the characteristic values are to be derived from a very small number of test results. ISO 12122-6 should be used in such circumstances to establish characteristic values or design properties with an appropriate level of reliability.

Commentary 1.7.2
The replication should be large enough to cover variants of the product that impact on the tested properties and give statistical significance to the result.

Where tests designed to provide information, such as the effect of angle of load to grain of the wood, minimum end distances, or minimum thickness of timber, are carried out at only one level of the variable being investigated, a similar number of specimens should be required. Where tests are conducted at more than one level of a single variable, a minimum of ten tests should be carried out at each level of the variable.

1.8 Test Conditions for Timber Samples

1.8.1 General Provisions

The specimens shall be kept for at least 14 days after assembly of the connection to allow for conditioning of the timber and relaxation of joint materials.

Commentary 1.8.1
Conditioning of the timber specimens should be undertaken before the manufacture of the joints and until testing. The conditioning should be conducted in such a way that the test conditions simulate the environment in which joints in prototype structures are exposed, in order to take into account the influence of the moisture content on the strength properties of the timber and the occurrence of gaps, etc., through shrinkage.

Where the purpose of testing is to compare joints under similar conditions, the standard atmosphere 20/65 according to ISO 554 should be used for conditioning; i.e. 65% relative humidity at 20°C.

1.8.2 Test Environment Conditions

1.8.2.1 Sample Moisture Content

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

Where tests are conducted at other equilibrium moisture contents to represent service conditions, the test report shall state the conditioning regime, measured moisture content, and temperature at the time of test.

1.8.2.2 Sample temperature

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

1.8.3 Standard Test Conditions

Samples are to be tested in seasoned condition where the moisture content of the timber remains lower than 15% (equivalent to standard conditions).

NOTE Recommendations for testing to determine the influence of moisture and moisture cycling are provided below:

Method 1: Assemble the test specimens at a moisture content of 12%. Divide samples into 2 groups. Test the control specimens at 12% and for the second group, increase the moisture content to the desired target equilibrium moisture content (EMC) and test.

Method 2: Assemble at 12%. Divide samples into 2 groups. Test the control specimens at 12% and for the second group cycle moisture and test at 12%. To assess impact of construction wetting it might also be appropriate to assemble the connections and test at the target (elevated) EMC.

> *Commentary 1.8.3*
> *For most species, an average uniform moisture content of approximately 12% can be achieved by exposure for a sufficient period to conditions approximating 65% relative humidity at 20°C. In situations where compliance with standard conditions is not achieved, adjustment of test data should be undertaken in accordance with Annex B of ISO 12122-1.*

1.9 Conduct of Tests

1.9.1 Apparatus

The tests shall be carried out in a testing machine of Class B or better (as defined in AS 2193) and of suitable capacity to ensure maximum load and deformation are achieved.

1.9.2 Loading Procedure

The application of load, measurement of force, slip and displacement shall be undertaken as specified in Section 2.

1.9.3 Moisture content and density

The moisture content and density of each specimen prepared shall be determined immediately after testing by the methods specified in AS/NZS 1080.1 and AS/NZS 1080.3, respectively.

1.10 Test Specimens for Joint Groups

The mean air-dry density of the timber selected to represent the joint group shall be lower than the group average density given in Table 1.1.

Table 1.1 Mean Density Range for Timber at 12% moisture content for Joint Groups

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

NOTE: For example, a sample of radiata pine with an average density of 520 kg/m^3 should be regarded as JD4.

> *Commentary 1.10*
> *For the purpose of joint design, AS 1720.1 classifies timber species into six joint groups, based upon the average density and assumed moisture content of the timber members in the service environment. The European approach for determining the characteristic value of a fastener in timber, is based upon determining the embedment strength of the timber, assuming a characteristic density equal to the 5th percentile density of timber. AS 1720.2 (2006) specifies the average density of radiata pine as 550 kg/m^3, which is approximately 10% to 15% higher than that observed in recent (as at 2024) testing of connections.*
> *For seasoned timber, this is the 5th percentile air dry density of timber at a moisture content of 12%. EN 338 specifies that the 5th percentile density can be estimated by dividing the average minimum density by a factor of 1.2.*

1.11 Determination of design capacity

The design capacity of the connection R_d for use with AS1720.1 shall be given as follows:

$$Design\ capacity\ of\ connections = R_d = \phi k_{mod} R_k \qquad \text{…Equation 1.1}$$

ϕ = capacity factors as given in AS1720.1

NOTE 1 k_{mod} =1 if the design conditions are the same as the test conditions.

NOTE 2 If the design conditions are not the same as the test conditions, then some judgement should 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.

NOTE 3 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 4 It is desirable that joints to be tested in tension should have the opportunity for self-alignment, and apparatus used for holding or supporting the specimens should, if practicable, be designed with this in view. Similarly, the use of a self-aligning head in the conduct of compression tests is preferred to one that is fixed.

Section 2 Test Procedures

2.1 Lateral Resistance Tests for Joints - General Requirements

2.1.1 Introduction

The tests are primarily intended to provide data from which characteristic properties for the various fasteners are derived for design purposes.

NOTE 1 The test methods may also be used for obtaining comparative data on various species of timber and other building materials, as well as data relating to the influence of various design variables known or expected to have a significant influence on the characteristic design loads.

NOTE 2: Special tests including those designed to determine the influence of various design variables, may require modifications to the test methods described herein. However, in the interests of standardization, the basic features of the described tests should be followed as closely as possible when conducting special tests, and such modifications, as may be made, should be the minimum necessary to meet the required conditions.

> *Commentary 2.1.1*
> *This Section sets out methods for determining the resistance to lateral movement offered by fasteners, when used with timber members to form structural joints. AS 1720.1 classifies these as Type 1 joints.*

2.1.2 Test specimens

The loaded end surfaces of a specimen to be tested in compression shall be essentially plane, square to the faces and parallel. The loading surfaces of the testing machine shall, if fixed, be parallel to within ±0.1 mm across the loaded surfaces of the joint assembly.

NOTE 1 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 centred to avoid unbalance loading

NOTE 2: For laterally loaded fasteners, experience has shown that the behaviour of some types of fasteners may not be identical when loaded in compression and tension. This is particularly relevant for connection assemblies tested under tension where the number of fasteners, the spacing, end and edge distances can result in a number of different failure modes.

> *Commentary 2.1.2*
> *Timber members forming a specimen to be tested in tension should be extended from the dimensions shown in the appropriate figures, to enable the attachment of suitable loading gear. The design of such loading gear should be such as not to affect the performance of the specimen and should be self-aligning so that the applied load is axial to the test specimen.*

If exploratory tests indicate that there may be an effect of loading direction, two series of tests shall be performed, one on specimens tested in compression and one on specimens tested in tension. The timber in all assemblies shall be density matched as noted in Clause 1.7.1.

> *Commentary 2.1.2*
> *The members in each joint should be taken from one stick or, if this is not practicable, from not more than two sticks, which should be from the same tree and closely matched. No special attention need be paid to growth-ring orientation in the members, i.e. whether they are quarter-sawn or back-sawn, unless this particular aspect is the subject of special investigation.*
>
> *Provision for conditioning the material and the specimens prior to test should be as given in Section 1. The moisture contents and densities of the members comprising each joint should be determined immediately after testing.*

2.2 Standard Loading Procedure – Lateral Loading

2.2.1 General Requirement

The following procedures are for static (monotonic) loading. To determine the characteristic capacities of connections, the test specimens shall be tested in accordance with Clause 2.2.2.

2.2.2 Test Methods

Unless the standard ISO loading procedure (Method 2) of Fig. 2.1(b) is requested, the static monotonic loading procedure (Method 1) as shown in Fig. 2.1(a) is the preferred test method to determine the stiffness characteristics and maximum load of a connection or connection assembly.

2.2.2.1 Application of load – Method 1

The testing machine shall record load with an accuracy of ± 2% or better and the recording instrumentation 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. The equipment shall ensure that eccentricities, twist, etc. have no influence on the measurements.

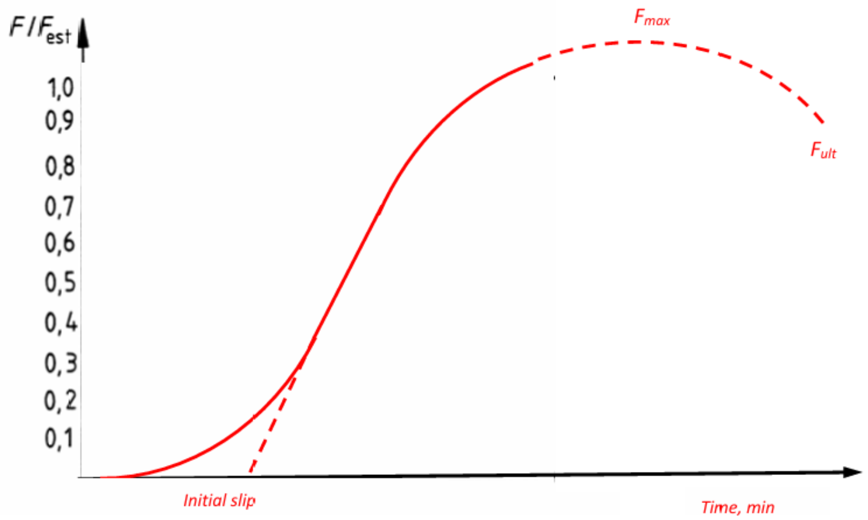


Figure 2.1(a) Method 1 Loading Procedure

The load shall be increased at a constant rate until the maximum load is reached. Each test shall record the speed of testing and shall be conducted using a loading rate such that the ultimate load is reached in between 2 and 10 minutes. For highly ductile specimens, it is important to continue loading beyond the maximum load in order to understand the ultimate failure behaviour.

NOTE 1 The maximum load should be reached in not less than 2 minutes and not more than 10 minutes. A constant movable crosshead speed of 2.5mm / minute ± 50 % usually permits reaching the maximum load within the prescribed time. However, it should be noted that weak specimens may fail in a time less than 1 minute. In such cases it is important that the results from the specimen(s) should be included in analysis of the series; any sample failing outside of the prescribed time due to material variability should be included in the dataset, to avoid biasing the results by removal of the lower strength results from "weak" specimens.

NOTE 2 Once the yield load is reached it will normally be difficult to maintain a constant rate of loading (load control). In such cases the load should be maintained at a level to ensure constant rate of deformation (displacement control).

NOTE 3 For loading under compression, the test may be stopped at an average displacement 20 mm, unless specifically required for the particular type of connection. There is rarely any observable benefit to continuing to load the specimen beyond a deformation of 20mm.

NOTE 4 Once the maximum load is reached it is possible to increase the loading rate to 5mm / minute, if the specimen exhibits observable ductility; i.e. continues to hold load whilst undergoing plastic deformation in either the fastener or the wood.

2.2.2.2 Application of load – Method 2

Loading rates shall be selected to target the loading pattern shown in Figure 2.1(b). The load shall be applied up to 0.4 x F_{est}, and maintained for 30 s. The load shall then be reduced to 0.1 x F_{est}, and maintained for 30 s. Thereafter the load shall be increased at a constant rate (see Note 2) until the maximum load or slip of 20 mm is reached. Each test shall record the speed of testing and shall be conducted using a loading rate such that the ultimate load is reached in approximately 10 min.

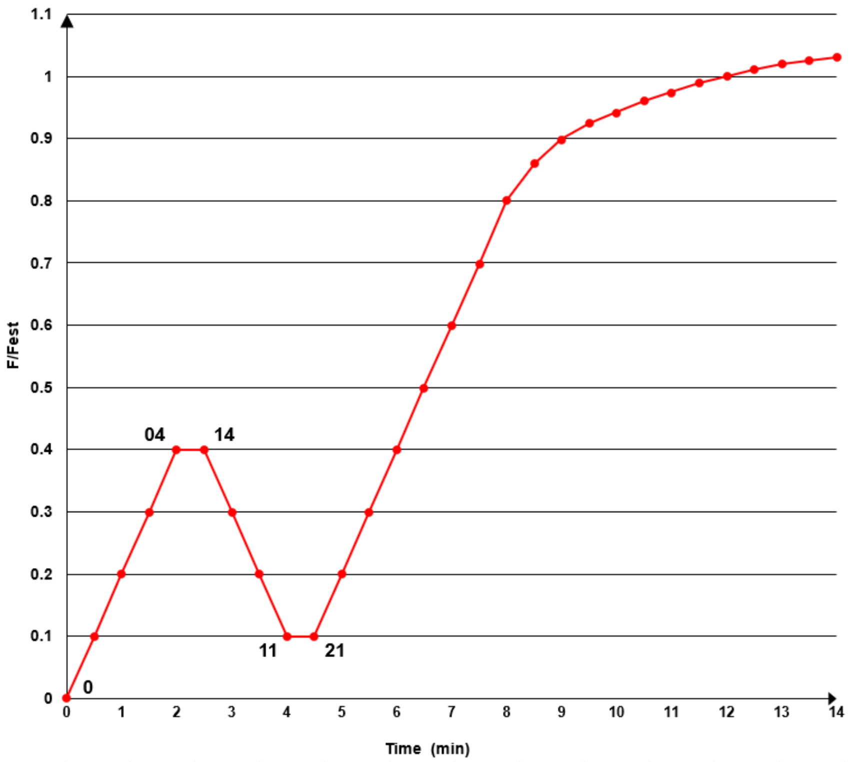


Figure 2.1(b) Method 2 Loading Procedure

NOTE 1 The maximum load should be reached in not less than 2 minutes and not more than 10 minutes. A constant movable crosshead speed of 2.5mm / minute ± 50 % usually permits reaching the maximum load in the prescribed time. However, it should be noted that weak specimens may fail in a time less than 1 minute. In such *cases it is important that the results from the specimen(s) should be included in analysis of the series; otherwise the results will be biased if all weak pieces are removed from the data because they failed in under 1 minute.*

NOTE 2 Once the yield load is reached it will normally be difficult to maintain a constant rate of loading (load control). In such cases the load should be maintained at a level to ensure constant rate of deformation (displacement control).

> *Commentary 2.2.2*
> *The standard ISO loading procedure (ISO 6891) is presented in Figure 2.1(b). However, preloading to 0.4 x F_{est} is not considered necessary, since any initial slip has to be taken into account for determination of both the stiffness of the connection and the yield point, using an offset equal to 5% of the fastener diameter.*

2.2.3 Estimation of maximum load – Method 2

The estimated maximum load, F_{est}, for the type of joint to be tested shall be based on theoretical calculations or preliminary tests. For most connections tested in accordance with the ISO 6891 method, $F_{PL} < F_{est} < F_{max}$ (refer Figure 2.1(b)). If, during the execution of the tests, the mean value of the maximum load of the tests already carried out deviates by more than 20% from the estimated value, F_{est}, then F_{est} shall be adjusted correspondingly for subsequent tests. The values of maximum load already determined may be accepted without adjustment, as part of the final results.

NOTE 1 If the connection is brittle and fails prematurely in the linear elastic range (for example when testing some types of connections under tension), or if the connection exhibits a high degree of non-linear behaviour between the Proportional Limit and the Maximum Load, F_{est} may need to be adjusted as noted above.

2.2.4 Measurement of slip

Slip or deformations shall be continuously measured (see note) using suitable displacement measurement devices such as Linear Variable Differential Transformer’s (LVDT).

The test shall be continued until the ultimate load is reached.

NOTE 1 Continuous measurement should be understood as recording readings of the slip at sufficiently frequent load intervals to permit establishment of a satisfactory average load-displacement curve. This will typically involve reading a measurement at a rate between 1 reading every 2 seconds, and 1 reading every 10 seconds. It is recommended that all measurements be recorded electronically using a suitable data acquisition system, that incorporates time coding. A data recording requirement of one reading every 2 seconds provides sufficient granularity to ensure the behaviour of the specimen under load, is captured accurately. There is no benefit in recording more frequently and more data points increases the time required for analysis of each test specimen.

NOTE 2 LVDTs or dial gauges are often removed when the load vs. deformation curve starts to become non-linear, and well before the maximum load point to avoid damage - but this may not be necessary for connections that undergo ductile failure modes. Measurement of the cross-head deflection is a useful alterative way of measuring deformation in the nonlinear range.

> *Commentary 2.2.4*
> *At least two displacement measurement devices positioned equidistant from the opposing connection surfaces are required to measure the slip between members of the connection from the initiation of load application. These devices should be attached in such a way that the amount of member deformation not associated with connection slip, is minimized. The measurements from these devices should be averaged to represent the slip of the connection. Details of typical test setups are presented in Appendix H.*
>
> *The general behaviour of the connection should be observed under load and observations of slip recorded; including the maximum load, the first abrupt decrease in load, the yield point and mode, the failure mode, and other significant details.*
>
> *When loading in accordance with Clause 2.2.3(a) measurement of slip should also be noted at points 0, 04, 14, 11, 21, as indicated in Figure 2.1(a). This requirement is not necessary for loading in accordance with Clause 2.2.3(b) since this method requires continuous measurement of both load and slip.*

2.2.5 Measurement of Load

The load and time of loading shall be measured and recorded to correspond with each measurement of slip, as noted in Clause 2.2.4 and Figure 2.1(a) and Figure 2.1(b).

2.3 Load-Displacement Curve Definitions

Each test undertaken in accordance with Clause 2.2 shall use the recorded measurements of slip and respective load, to produce a graph of the complete load – displacement curve, as indicated in Figure 2.2 and Figure 2.3.

> *Commentary 2.3*
> *Definitions of each significant load and deformation point on these idealised graphs are presented below. For additional information on determining each of these characteristics refer to EN 12512 and ISO 21581.*

2.3.1 Initial Stiffness

The initial stiffness of a connection is determined as the slope of the straight line fitted to the initial linear portion of the average load-displacement curve.

This is calculated as the slope of the loading-displacement curve prior to unloading, between 0.1 x F_{est} and 0.4 x F_{est} in Figure 2.2.

For the modified loading method (Figure 2.3), the initial stiffness (below a load of approximately 0.2 x F_{max}) is not required to be determined.

2.3.2 Design Stiffness

The design stiffness of a connection is determined as the slope of the straight line fitted to the initial linear portion of the average load-displacement curve.

NOTE 1 In many connection tests (particularly for bolted joints), initial slip can occur as soon as loading commences, creating an initial offset from the origin, as indicated by the dashed line near the origin in Figure 2.3. In these cases, the initial stiffness is not relevant, but the amount of slip should be determined and accounted for, in order to apply the 5% offset to determine the yield point, F_y. This is explained in detail in Appendix D.

NOTE 2 Commencing determination of the connection stiffness at a minimum load of approximately 0.2 x F_{max} will normally ensure that the average load-displacement curve is linear as loading increases.

> *Commentary 2.3.2*
> *It is calculated as the slope of the loading-displacement curve after reloading, between 0.1 x F_{est} and F_{PL} in Figure 2.2. For the modified loading method (Figure 2.3), the design stiffness is determined as the slope between 0.2 x F_{max} (or the load at which the slope starts to be linear) and F_{PL}.*

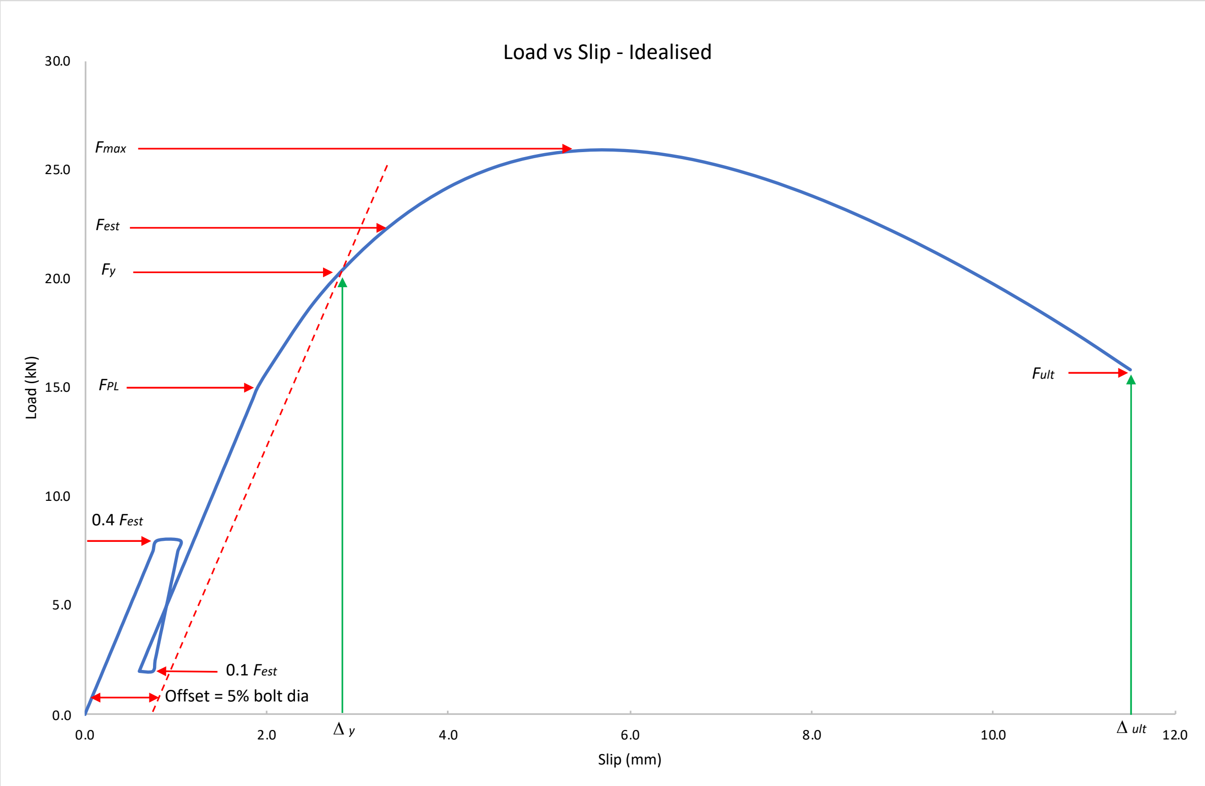


Figure 2.2 Definition of Load and Deformation points (ISO loading curve)

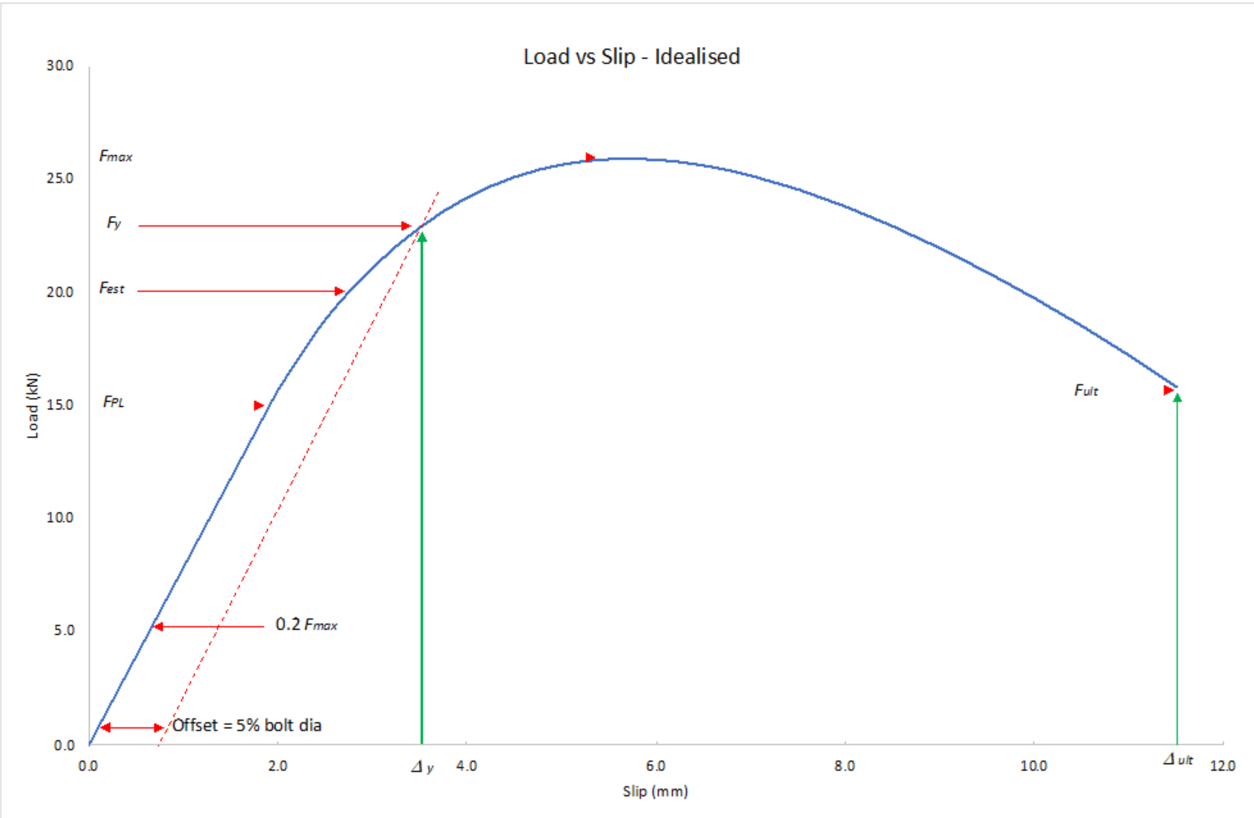


Figure 2.3 Definition of Load and Deformation points (modified loading curve)

2.3.3 Proportional Limit Load

The proportional limit load F_{PL} is determined as the load at which the average load-displacement curve deviates from a straight line fitted to the initial linear portion of the curve.

2.3.4 Yield Load

To determine the connection yield load F_y, fit a straight line to the initial linear portion of the average load-displacement curve, offset this line by a displacement equal to 5% of the measured fastener diameter, and select the load at which the offset line intersects the average load - displacement curve.

Commentary 2.3.4
In those cases where the offset line does not intersect the average load-displacement curve, the maximum load should be assumed to be the yield load.

2.3.5 Maximum Load

The maximum load, F_{max}, is the maximum absolute value.

2.3.6 Ultimate Load and Displacement

The ultimate load F_{ult} is that at which the connection fails and is no longer able to resist application of force.

Commentary 2.3.6
For connections that exhibit either brittle or limited non-linear behaviour, the ultimate load F_{ult} will equal the maximum load F_{max}. Ultimate load may be reach when the load drops below 20% or more of F_{max}. The ultimate displacement, Δ_{ult} is the slip that is measured at the ultimate load.
For connections exhibiting ductile behaviour the ultimate load is likely to be less than the maximum load,

2.3.7 Ductility

Ductility is defined as the ratio of the ultimate displacement to the yield displacement, expressed as:

$$\mu = \frac{\Delta_{ult}}{\Delta_y} \qquad \text{…Equation 2.1}$$

2.3.8 Failure modes

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

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

> *Commentary 2.3.8*
> *For laterally loaded connections within the scope of this Standard, a number of different failure modes are possible, including:*
> *1. Failure of the fastener / connection assembly (in bending)*
> *2. Failure of the timber parallel to grain (in tension, compression or shear)*
> *3. Failure of the timber perpendicular to grain (in tension or compression)*
> *4. Splitting or tear out failures of the timber*
> *All potential failure modes should be noted, and details recorded.*
> *The load – deformation behaviour of each of these failure modes will vary. With reference to the idealised curves shown in Figures 2.2 and 2.3:*
> *• Joints where significant deformation occurs after F_{max} is reached, can be considered to exhibit ductile behaviour prior to failure at F_{ult}.*
> *• Joints where a limited amount of deformation occurs, prior to Fmax, will exhibit non-linear behaviour as a result of either embedment (localised bearing) failure in the timber or yielding of the fastener(s). In such cases F_{max} = F_{ult} where F_{max} is greater than F_y.*
> *• Joints where failure occurs suddenly without exhibiting any marked non-linear behaviour can be considered brittle. In such cases F_{max} = F_{ult} where F_{max} is less than F_y.*

2.4 Withdrawal Test for Joints – General Requirements

2.4.1 Introduction

This Section sets out a basic procedure for determining the resistance to axial (direct) withdrawal offered by fasteners such as nail, staples and screws, when used with timber members to form structural joints. AS 1720.1 classifies these as Type 2 joints.

NOTE 1 The test methods may also be used for obtaining comparative data on various species of timber and other building materials, as well as data relating to the influence of various design variables known or expected to have a significant influence on the characteristic design loads.

NOTE 2 Special tests including those designed to determine the influence of various design variables, may require modifications to the test methods described herein. However, in the interests of standardization, the basic features of the described tests should be followed as closely as possible when conducting special tests, and such modifications, as may be made, should be the minimum necessary to meet the required conditions.

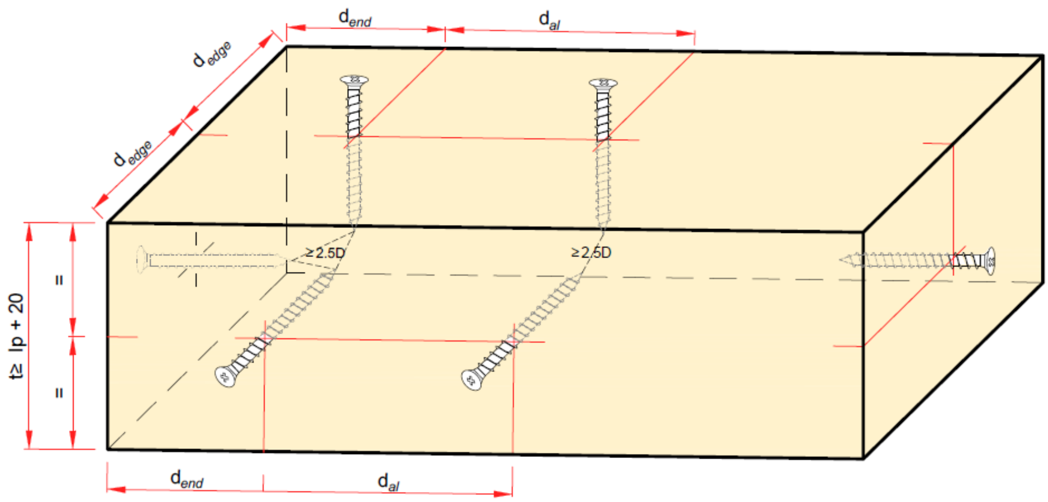
> *Commentary 2.4.1*
> *The tests are primarily intended to provide data from which characteristic properties for the various fasteners are derived for design purposes.*
> *The test procedure is based on the provisions of AS1649 and ASTM D1716-12.*

2.4.2 Test specimens

Nail and screw withdrawal tests shall be made on timber specimens in accordance with the requirements of AS 1720 and as per Figure 2.4. The thickness of the specimens shall be at least l_p + 20 (mm) for both nail and screw tests, where D = nail or screw diameter and l_p = penetration of the fastener, both in millimetres – refer Figure 2.4.

For nails, the depth of penetration shall be the greater of 10D or 50% of the length of the fastener.

For screws, the depth of penetration shall be the greater of 10D or 50% of the thread length.



Spacing type	Minimum Distance		
	Nails		Screws
	Holes not predrilled	Holes predrilled to 80% of nail diameter	
Edge distance (d_{edge})	5D	5D	5D
End distance (d_{end})	20D	10D	10D
Spacing between fasteners along the grain (d_{al})	20D	10D	10D

NOTE: Additional requirements such as points of the fasteners do not pass closer than 2.5D are not included in the spacings and may need consideration.

Figure 2.4 Test Specimen

Tests on other types of fasteners, such as staples, shall be made on specimens of such thickness as to allow the fastener to be driven to the correct depth without complete penetration of the specimen. Other dimensions shall be such that distances between the fastener and the edges and ends of the specimen shall be sufficient so that splitting will not occur.

2.4.3 Preparation of test specimens – nails

For tests determining withdrawal capacity of side grain, two nails shall be driven into each of two adjacent faces of the specimens. For tests determining withdrawal capacity of end grain, one nail shall be driven centrally into each end of the timber specimen. The nails at right angles to each other shall be so positioned that the points of the nails do not pass closer than 2.5*D* to each other – see Figure 2.4. Any deviation from Figure 2.4 shall be noted.

NOTE End and edge distances and spacings in accordance with Figure 2.4 are typically sufficient to avoid splitting. If splitting occurs, this is to be noted and greater end and edge distances to be tested so that splitting will not occur.

Nails shall be driven without pre-drilling in wood or wood-based material of an air-dry density less than 720 kg/m3. The nails must be driven into pre-drilled holes in material of an air-dry density exceeding 720 kg/m^3, the diameter of which shall not exceed 80% of the nail diameter.

Measure, weight, and calculate the density of each piece of timber.

2.4.4 Preparation of test specimens – screws

Preparation of the specimens for screw withdrawal tests shall follow a similar pattern to that described in Clause 2.4.2. Where a lead hole is required the diameter of the hole shall be equal to the diameter of the shank and the predrill hole for the threaded portion of the screw shall not be greater than the root diameter of the screw.

The screws may be lubricated to facilitate driving.

Specimens shall not be pre-drilled if fasteners, which are designed for use without pre-drilling, are being tested.

2.5 Loading Procedure for Fasteners Subject to Withdrawal

2.5.1 Loading Protocol in Accordance with Section 2.2.2(a)

The test method to determine the withdrawal capacity of a fastener, or connection assembly, shall be in accordance with the modified loading procedure, shown in Figure 2.1(a), and the load shall be increased until failure occurs.

The equipment shall ensure that eccentricities, twist, etc. have no influence on the measurements. Specific requirements of the test procedure for fasteners subject to withdrawal are specified in Section 4.

The maximum load shall be reached in not less than 2 minutes and not more than 10 minutes.

Section 3 Specific Requirements for Laterally Loaded Timber Joints

This Section describes the procedures for undertaking testing of specific joints and connection assemblies, in accordance with the general provisions of Section 2. This includes testing procedures that must be undertaken in order to derive the relevant design properties for use with AS 1720.1

3.1 Test Details for Connection Assemblies

General details for both joint categories are illustrated schematically in Figure 3.1.

Commentary 3.1
As noted in the Scope, the procedures contained in this Standard are limited to 3-member joints, fabricated using Category A and Category B Fasteners; specifically nails, screws, bolts and dowels, manufactured from steel to a relevant standard.
Category A fasteners are typically nails and screws connecting each side member into the central member, with each fastener loaded in single shear. Category B fasteners are typically bolts or dowels inserted into predrilled holes and passing through all three members of the joint, where each fastener is loaded in double shear.

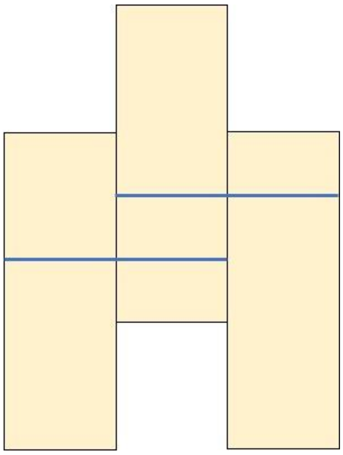


Figure 3.1a Category A

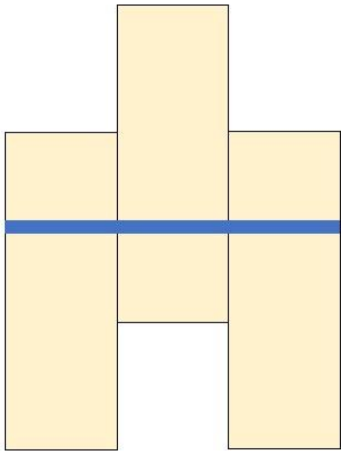


Figure 3.1b Category B

3.1.1 General Joint Configuration for Compression Testing of Category A fasteners

The specimen shall be comprised of three members fastened in the form shown in Figure 3.2. The fasteners shall be driven into the faces of the members, with the timber faces as close as possible. All details of the connection geometry, such as edge and end distances and the method of assembly, shall be fully documented. In cases where the joint has multiple fasteners, the centre-to-centre spacing between individual fasteners, in both directions (parallel to grain and perpendicular to grain) shall also be fully documented and the details of such spacings and geometry shall be noted in the test report.

In timbers of density less than 720 kg/m^3, which show little tendency to split, nails may be driven without pre-drilling. For screws in such timbers, the hole for the shank shall be not less than 90% of the shank diameter (unthreaded diameter) and the diameter of the lead hole in the centre member shall be not greater than the minor diameter of the screw. For timbers of density greater than 720 kg/m^3, predrilling shall be undertaken prior to inserting the fastener(s), unless the fasteners are gun driven.

Each joint shall be tested in a testing machine of suitable capacity, in accordance with the requirements of Clause 1.9. Provision shall be made for measuring the average displacement during the test of the outer members relative to the inner member; with an accuracy of not less than ± 1 %, or for slip of less than 2 mm with an accuracy of not less than ± 0.02 mm. The load shall be applied continuously throughout the test at a rate of crosshead movement and all test data recorded in accordance with the provision of Section 2.

NOTE The basic features of the specimen illustrated in Figure 3.4 should be adopted when testing fasteners for three-member timber connections or for the fastening of sheet materials or steel side plates to timber.

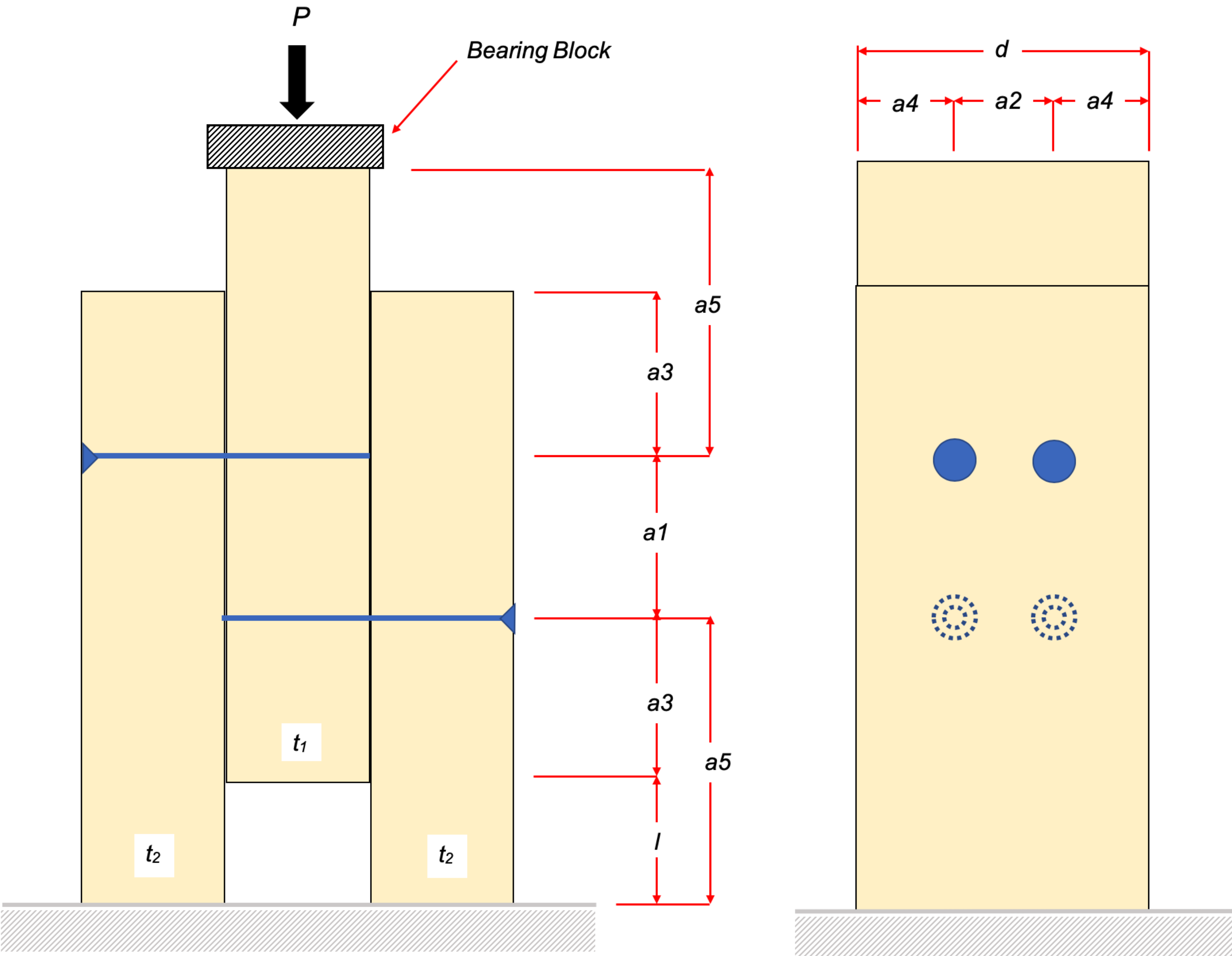


Figure 3.2 Configuration for Category A

Note:

L = the length of the fastener (mm)

D = diameter (root diameter in the case of screws) of the fastener (mm)

For 3-member timber-to-timber connections, the following dimensions are recommended, unless specifically testing alternative connection geometries:

$t_1 \geq 10D$ & $t_2 \geq 10D$ for fasteners in single shear (thickness of the timber members)

$t_1 \geq 10D$ & $t_2 \geq 7.5D$ for fasteners in double shear (thickness of the timber members)

$d \geq$ = at least 14D (depth of the timber members)

l = at least 25mm (member offset to permit relative deformation)

a_1 & $a_3 \geq 10D$ (centre to centre spacing parallel to grain and end distance)

a_2 & $a_4 \geq 5D$ (centre to centre spacing perpendicular to grain and edge distance)

$a_5 \geq (a_3 + l)$

3.1.2 General Joint Configuration for Compression Testing of Category B fasteners

Two types of specimens, Parallel Type and Perpendicular Type, are specified for this fastener category. The specimens of each type shall be comprised of three members assembled in the form shown in Figure 3.3 for Parallel Type and in Figure 3.4 for Perpendicular Type. All details of the connection geometry, such as edge and end distances and the method of assembly, shall be fully documented. In cases where the joint has multiple fasteners, the centre-to-centre spacing between individual fasteners, in both directions (parallel to grain and perpendicular to grain) shall also be fully documented and the details of such spacings and geometry shall be noted in the test report.

The size of washer (if required) and diameter of the fastener, and any necessary preparation of the specimen members, such as drilling or grooving, and the assembly of the complete joint shall be as specified. In cases where the connection incorporates steel plates, two configurations are possible: (i) 1 steel “fin” or centre plate with 2 timber side members and, (ii) 2 steel side plates with a timber centre member. The dimensions of the steel plates shall be as specified by the manufacturer.

For Perpendicular Type specimens, the inner member shall be seated on suitable supports spaced not closer than $1.5w_2$ from the centre-line of the joint, as noted in Figure 3.4(a).

Each joint shall be tested in a testing machine of suitable capacity, in accordance with the requirements of Clause 1.9. Provision shall be made for measuring the average displacement during the test, of the outer members relative to the inner member; with an accuracy of not less than ± 1 %, or for slips of less than 2 mm with an accuracy of ± 0.02 mm. The load shall be applied continuously throughout the test at a rate of crosshead movement and all test data recorded in accordance with the provision of Section 2.

NOTE The basic features of the specimen illustrated in Figure 3.3 should be adopted when testing fasteners for three-member timber connections or for the fastening of sheet materials or steel side or centre plate(s) to timber.

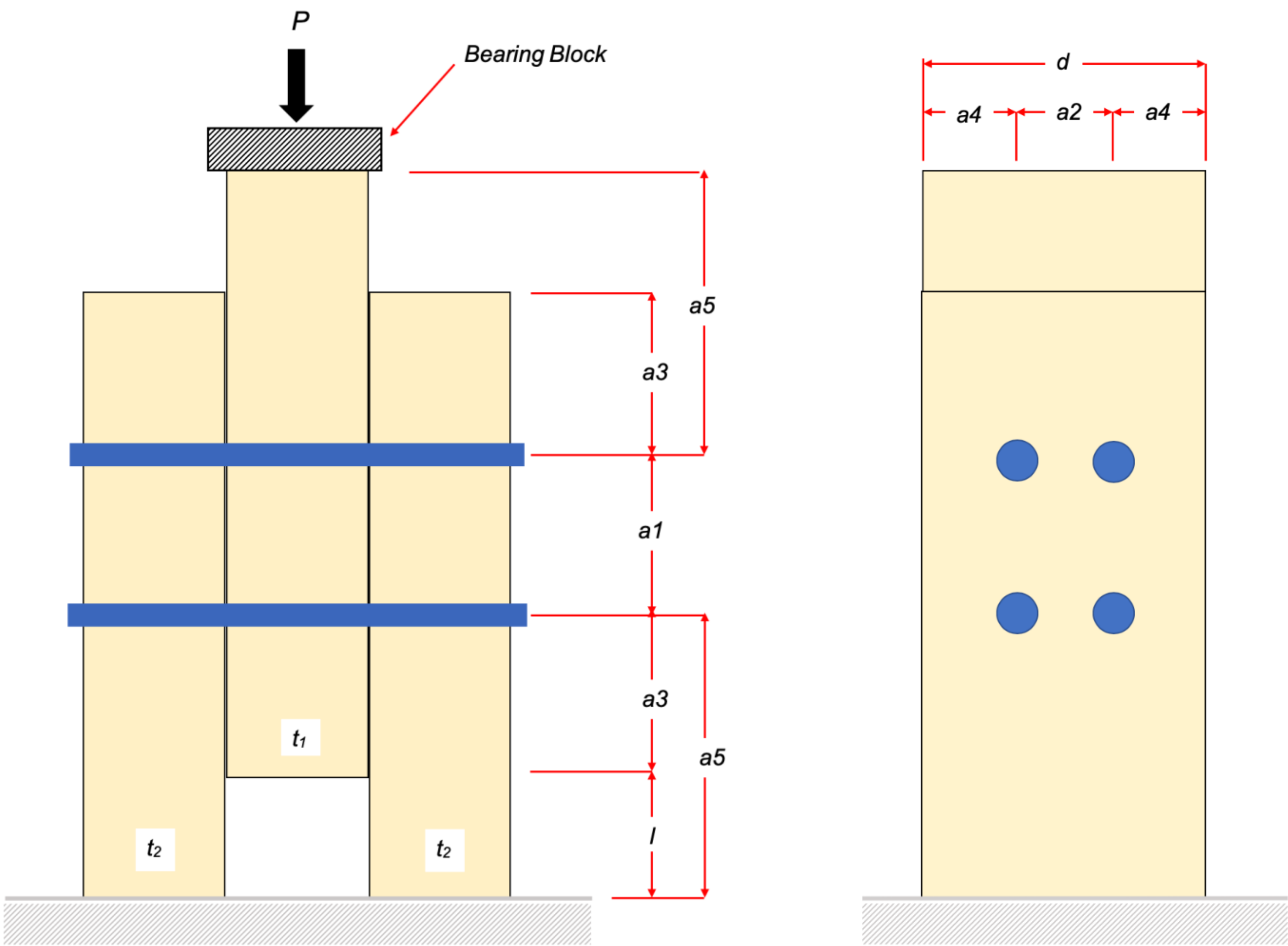


Figure 3.3 Configuration for Category B parallel to grain

Dimensions in millimetres.

D = diameter of the fastener

t_1 = thickness of the timber centre member

t_2 = thickness of the timber side members

d = width of the timber members

l = at least the greater of 50mm and 1.5 * t_1 (member offset to permit relative deformation)

a = end distance

For 3-member timber – timber connections loaded parallel to grain, the following dimensions are recommended, unless specifically testing alternative connection geometries:

$a_1 \geq 4D$ (centre to centre spacing parallel to grain); note: AS1720.1 specifies $\geq 5D$ for washer size

$a_2 \geq 3D$ (centre to centre spacing perpendicular to grain) note: AS1720.1 specifies $\geq 4D$ for washers

$a_3 \geq$ MAX [$4D$ or 50mm] (end distance)

$a_4 \geq$ MAX [$2D$ or $1.5a_2$] (edge distance)

$a_5 \geq (a_3 + l)$

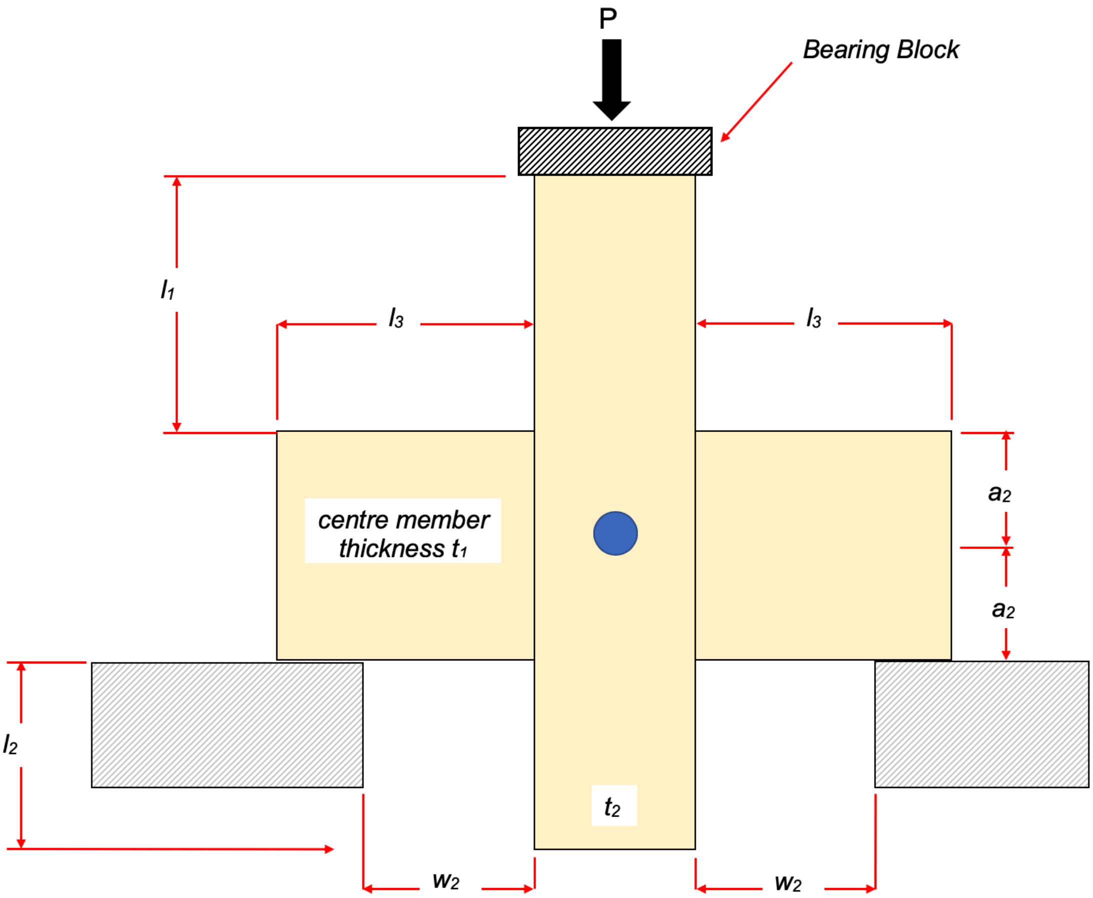


Figure 3.4(a) Configuration for Category B – perpendicular to grain
(where necessary, the middle member may need to be braced to prevent rotation)

D = diameter of the fastener

t_1 = thickness of the timber centre member

w_2 = t_2 width of the timber side members

l_1 = at least, the greater of 50mm and 5D

l_2 = at least the greater of 50mm and 4D

l_3 = at least the greater of 150mm and 10D

a_2 = edge distance

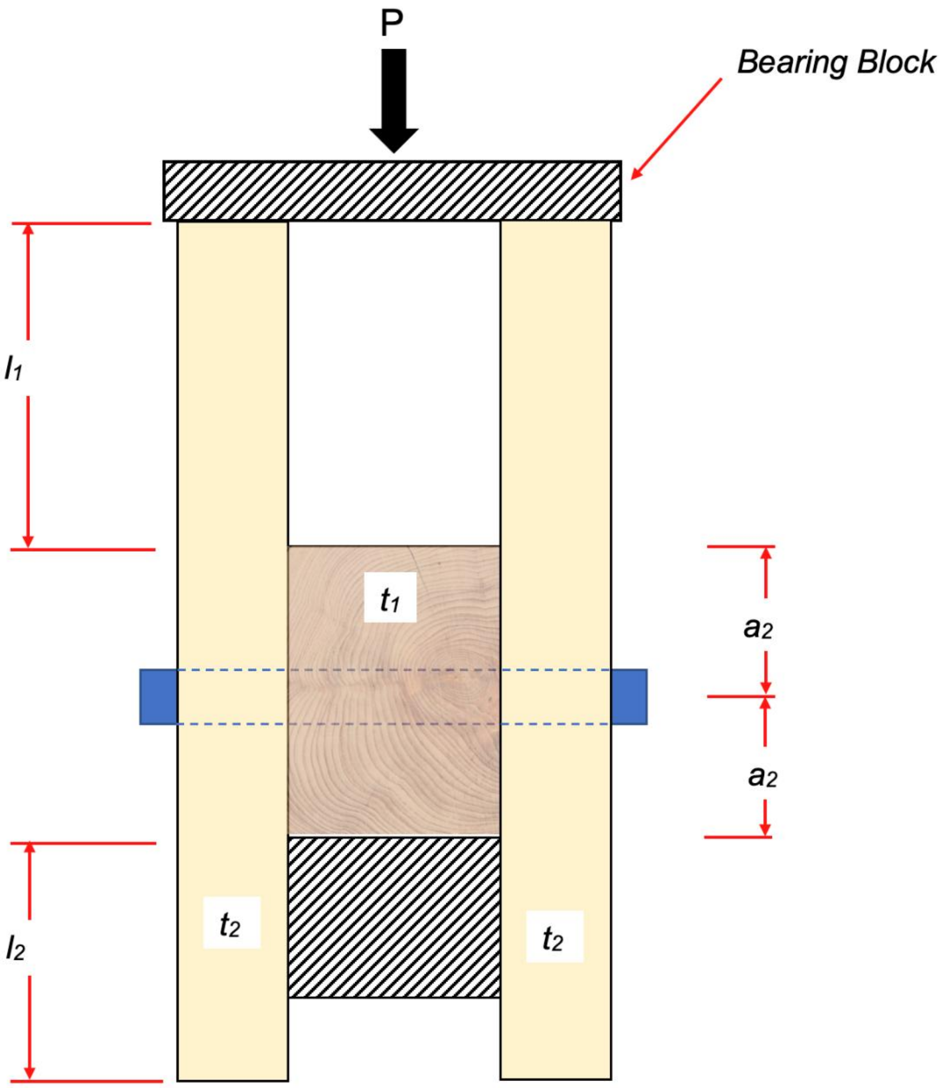


Figure 3.4(b) Configuration for Category B – perpendicular to grain (side view)

D = diameter of the fastener

t_1 = thickness of the timber centre member

t_2 = thickness of the timber side members

l_1 = at least, the greater of 50mm and 5D (member offset to permit relative deformation)

l_2 = at least the greater of 50mm and 4D (member offset to permit relative deformation)

a_2 = edge distance

3.1.3 General Joint Configuration for Tension Testing of Category A and B fasteners

When the effect of loading direction is not known, two series of tests shall be initially performed, one on specimens tested in compression and one on specimens tested in tension. For the purposes of this initial study, a minimum of three specimens shall be tested under compression and three under tension. If different failure modes are observed in the preliminary tests, or if there is a significant difference at the 10%ile level between the means of tension and compression tests, then a full series of both tension and compression tests must be completed as specified in Clause 1.7.2. The results of the preliminary tests can be included in the total number of tests.

The test report must clearly state whether the testing of connection assemblies was carried out under tension or compression loading.

NOTE Connections tested in tension are more representative of behaviour in service than those tested in compression; therefore, application of tensile load is preferred in many situations.

> *Commentary 3.1.3*
> *It is noted that for laterally loaded fasteners, experience has shown that the behaviour of some types of fasteners may not be identical when loaded in compression and tension. Some failure modes for timber can only be identified if the connection assembly is loaded in tension.*
> *Whilst testing under compression is relatively easy in terms of set-up of the specimens, testing under tension will often require additional fabrication (in the case of steel plates – either side or slotted) or be limited in size to ensure adequate gripping of the timber members so as to ensure that unintended slip does not occur.*

The method of testing a connection in tension parallel to the grain or strength-axis is shown schematically in Figures 3.5 and 3.6. Design of the ends of the members where tensile loads are applied is required to ensure failure away from the gripping devices. Timber members forming a specimen to be tested in tension (as indicated in Figure 3.7(L)) shall have the centre members extended from the basic dimensions shown in Figures 3.2 and 3.3, to enable the attachment of suitable "gear" (grips or plates) that enable loading to occur. The design of such loading gear shall be such as not to affect the performance of the specimen and shall be self-aligning so that the applied load is axial to the test specimen.

NOTE The relative thickness of the centre members and the side members, shown in Fig 3.7(L) will determine the characteristic capacity of the connection system. As such, a minimum of 10 specimens should be tested for each variation of the ratio of member thickness, t_1 to t_2. Where the purpose of testing is intended to apply load to be distributed equally to the timber members, it is recommended that $t_1 = 2\,t_2$.

For members loaded parallel to grain, the minimum end distance for tension loading shall be at least 7*D* but not less than 80mm (where "*D*" is the fastener diameter), unless the effect of shorter end distances is to be specifically investigated. The minimum distance (spacing) between fasteners in Figure 3.6(R) shall be at least 5*D*, both along and across the grain, unless the effect of shorter spacing is to be specifically investigated.

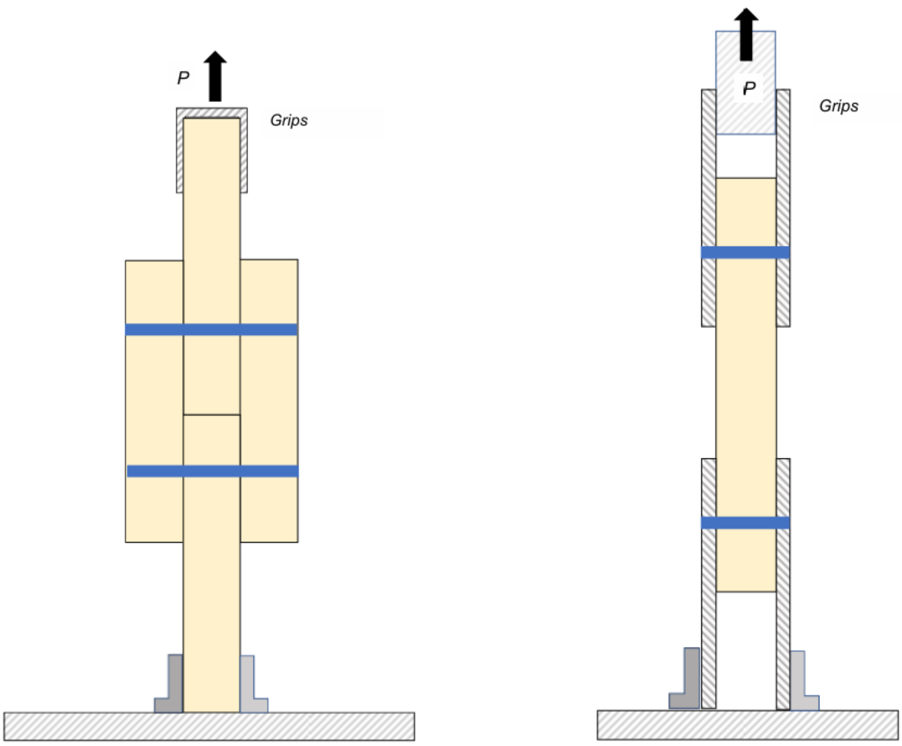


Figure 3.5 Schematic Configuration for Tension: (L) Timber only; (R) Steel side plates

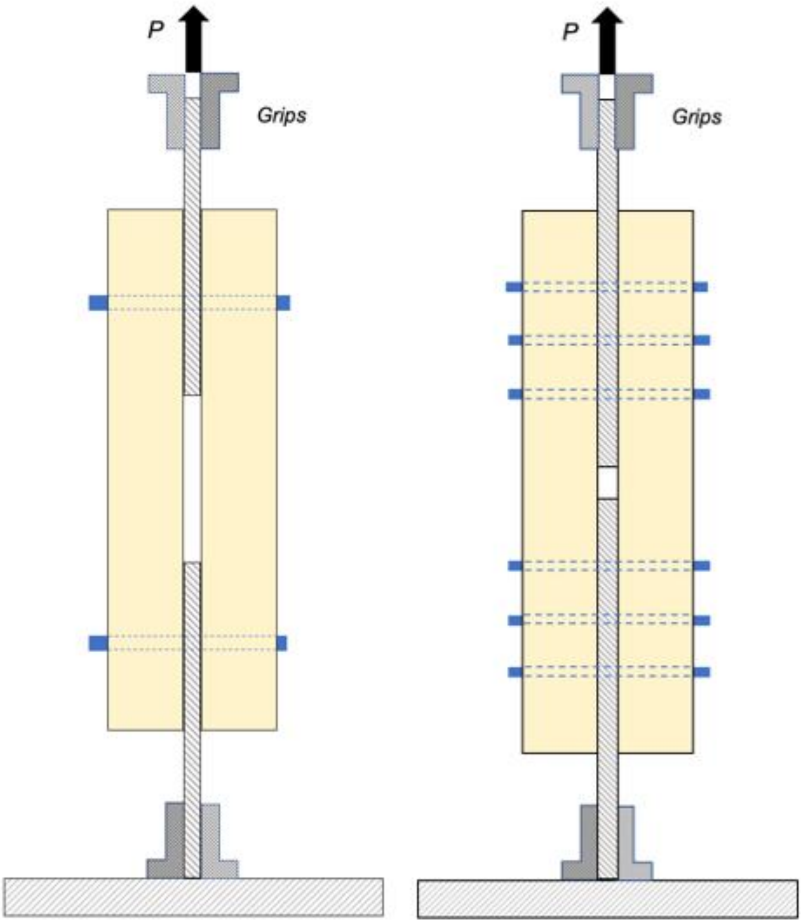


Figure 3.6 Schematic Configuration for Tension: Steel centre or "fin" plate connection

NOTE The basic features of the specimen illustrated in Figure 3.4 should be adopted when testing fasteners for three-member timber connections or for the fastening of sheet materials or steel side plates to timber.

3.2 Testing of Large Connection Assemblies

The general principles specified in this Standard can be used for testing of full scale, prototype connections; including axially loaded or moment resisting connections. Additional requirements include:

1) Loading Specification: Loading points, load – time history, restraints, deformations (local and global), any variance from standard conditions and whether the load is applied by deformation or force control shall be listed. The load sequencing and application shall be defined so as to represent the anticipated load events required to be resisted by the connection assembly in a structure.

2) Testing Arrangement and Set-up: The test equipment shall be relevant for the type of tests and the expected range of measurements. Special attention shall be given to the set up to ensure sufficient strength and stiffness of the loading and supporting rigs, prevent out-of-plane actions and maintain clearance for deflections and deformations. Prior to the testing, all relevant properties to be measured for each individual test specimen shall be listed.

Commentary 3.2 *Guidance on testing of full scale, prototype connection assemblies is presented in Appendix B.*

Section 4 Specific Requirements for Withdrawal Tests

This Section describes the procedures for undertaking testing of specific joints and connection assemblies, in accordance with the general provisions of Section 2. This includes testing procedures that must be undertaken in order to derive the relevant design properties for use with AS 1720.1.

4.1 Test procedures for nails, staple or screws

Commentary 4.1
For determining the withdrawal resistance of particular sizes and shapes of nails or staples in wood or wood products, the specimen should be of convenient size to accommodate the quantity of fasteners to be tested in each specimen, without exceeding the edge and end distances and spacings necessary to avoid splitting. Tests on other types of fasteners, such as staples, should be made on specimens of such thickness as to allow the fastener to be driven to the correct depth without complete penetration of the specimen. Other dimensions should be such that distances between the fastener and the edges and ends of the specimen should be sufficient for correct performance of the fastener and so that splitting will not occur.

The fasteners shall be driven by the method intended to be used in practice, that is, either manually with a hammer, or with an applicator or appropriate tool if this is the normal method.

(a) Each fastener shall be withdrawn by means of a tensile load applied axially to the fastener in a testing machine of suitable capacity. A gripping device shaped to fit the base of the fastener head and of such a design as to allow accurate specimen positioning and true axial loading, is required. The specimen shall be clamped and firmly supported to one platen of the test machine so that the load is fully applied to the fastener connected to the wood test specimen, by a grip shaped to fit the base of the fastener head.

(b) The load shall be applied continuously throughout the test

(c) Slip or deformations if required shall be continuously measured using suitable instrumentation to measure the relative movement of the load actuator, with the corresponding load being also recorded. The maximum load (P_{max}) and depth of penetration of each withdrawal test shall be noted.

(d) P_{max} shall be divided by fastener embedded depth or for partially threaded fasteners the embedded thread length plus tip to express withdrawal strength in N/mm of embedded thread length

(e) Appropriately designed tests shall be conducted to determine the strength in tension of the fastener itself.

(f) For some fasteners in withdrawal, pull-through of the fastener's head through the timber may limit the withdrawal or axial capacity of the fastener. Where preliminary investigation indicates this may be a consideration, appropriately designed tests shall be conducted to determine the head pull-through resistance of the fastener itself.

NOTE 1: Generally, the tensile strength can be determined by inserting the fastener sufficiently deeply into a timber specimen to ensure that the withdrawal load substantially exceeds the tensile strength of the fastener.

NOTE 2: A constant movable crosshead speed of 2.5mm / minute ± 50 % usually permits reaching the maximum load in the prescribed time.

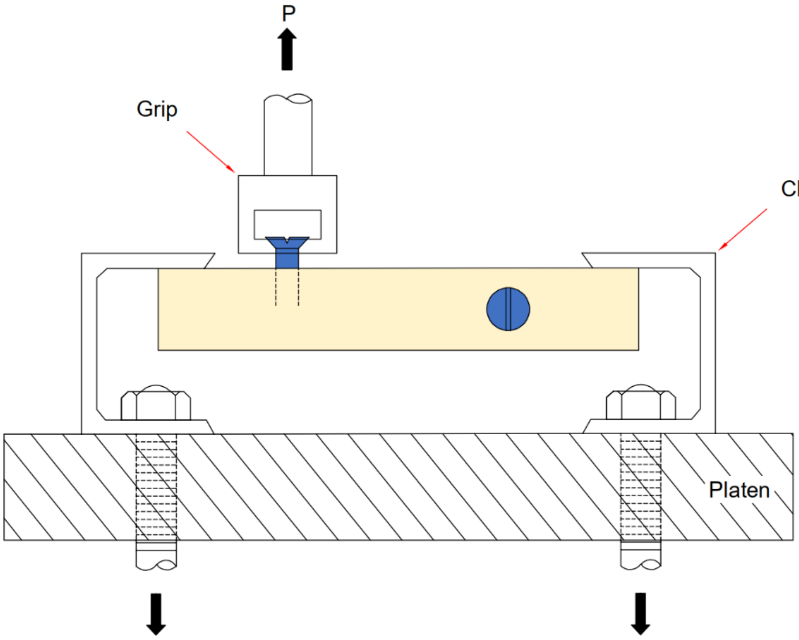


Figure 4.1 Schematic diagram of assembly for screw (or nail) withdrawal

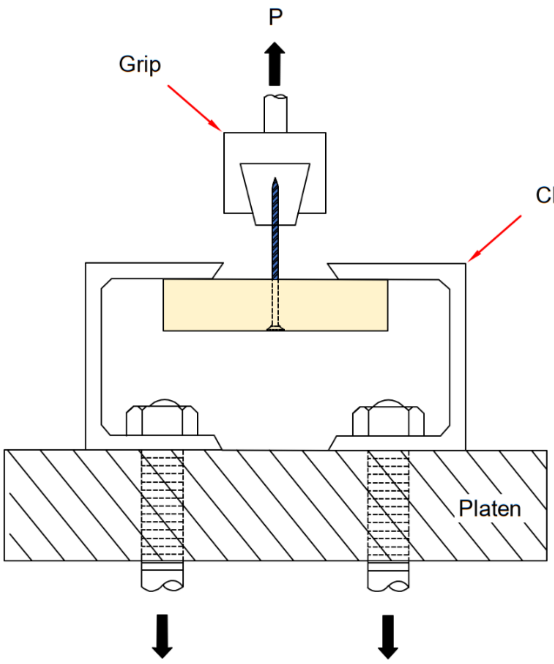


Figure 4.2 Schematic drawing of assembly for screw (or nail) head pull through

Section 5 Analysis Methods

This Section defines a framework for establishing characteristic values from test results on a sample drawn from a clearly defined reference population. The requirements of Clause 5.1 and 5.2 shall be used to determine two characteristic values with 75% confidence:

(i) Mean stiffness in accordance with 5.1

(ii) 5th percentile strength in accordance with 5.2

Analysis of the test data shall be undertaken in accordance with AS/NZS 4063.2 where the characteristic value is defined as an estimate of the property of the reference population with a consistent level of confidence. AS/NZS 4063.2 presents methods for the determination of:

a) characteristic value of mean-based properties, and

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

NOTE As noted in Clause 3.2, where there is no reference population or the testing program involves a limited number of connection assemblies, alternative methods should be used to determine either characteristic strength or design properties – refer Appendix B.

Commentary 5
AS/NZS 4063.2 can be used on any structural product, and it presents normative statistical means for analysis of data in order to determine the characteristic values. This Standard provides evaluation methods where the sample size is not less than 30 or, for a tail-fit analysis, not less than 100. For sample sizes of 10 (the minimum of specimens specified in Clause 1.7.2), AS/NZS 4063.2 can be used subject to the requirements of Clauses 5.1 and 5.2 below.
The relevant ISO Standard for determination of characteristic values is ISO 12122-1, which presents the essential statistical procedures for analysis of test data, obtained from experimental testing undertaken in accordance with ISO 6891. AS/NZS 4063.2 is a Normative reference for ISO 12122-1 and complies with the requirements of the International Standard for non-parametric analysis of test data.

AS 4063.2 shall be used, in accordance with the requirements of Clauses 5.1 and 5.2, to determine characteristic values with 75% confidence for:

1) The Mean stiffness
2) The 5th percentile Maximum or Ultimate load
3) The Mean ultimate displacement (where relevant)

5.1 Characteristic values for stiffness

Characteristic values for stiffness shall be determined using one of the following procedures.

5.1.1 Procedure 1

The assessment of characteristic values for stiffness is based on the assumption that the distribution of data is lognormal and shall be derived using the complete sample test data. The characteristic value for stiffness ($E_{k,mean}$) shall be taken as the lesser of $E_{k,mean,1}$ and $E_{k,mean,2}$ calculated using the following equations specified in AS/NZS 4063.2 Appendix B3:

$$E_{k,mean,1} = k_s\, E \qquad \text{…Equation 5.1 (a)}$$

$$E_{k,mean,2} = \frac{k_s\, E_{05}}{0.7} \qquad \text{…Equation 5.1 (b)}$$

Where:

k_s = sampling factor (Equation 5.3).

E = mean stiffness of test data, in N/mm

E_{05} = 5th percentile value for stiffness of the test data, in N/mm

NOTE An example of data analysis using Equations 5.1(a) and 5.1(b) in an Excel spreadsheet, is given in Appendix C, for test samples of 10 specimens and 30 specimens respectively.

5.1.2 Procedure 2

This method is applicable for sample size $n \leq 30$ and the coefficient of variation of stiffness of the reference population $V_R \leq 40\%$.

Characteristic value for stiffness E_K is given by:

$$E_k = \frac{E_m}{k_m} \qquad \text{…Equation 5.2}$$

Where:

E_m = mean test value of stiffness assumed to be approximately the same as that of the reference population.

K_m = sampling factor to raise the level of confidence to 75%.

Table 5.1 Sampling factors K_m for mean-based properties with 75% confidence – lognormal distribution

Sample size *(n)*	Coefficient of variation of the reference population			
	10%	20%	30%	40%
10	1.02	1.04	1.06	1.08
20	1.01	1.03	1.04	1.06
30	1.01	1.02	1.04	1.05

NOTE Details and worked examples can be found in Appendix B.

5.2 Characteristic values for strength

Characteristic values for strength shall be determined using one of the following procedures. The characteristic strength shall be multiplied by a modification factor of 0.8 using Procedure 1 or 2 when the coefficient of variation is between 20% and 40%, and the capacity factors in AS 1720.1 for nails, screws, and bolts and coach screws of M16 diameter and smaller are to be adopted.

Note: For most cases, it is expected that the coefficient of variation for Categories A and B fasteners tested within the scope of this document will lie between 10% and 20%. However, where the coefficient of variation is between 20% and 40%, and the capacity factors specified in AS 1720.1 for nails, screws, and bolts and coach screws of M16 diameter and smaller are adopted, a modification factor of 0.8 shall be applied. This adjustment to the characteristic value is necessary to maintain the level structural reliability used for the derivation of design strength in AS 1720.1. The modification factor of 0.8 is not required for bolts and coach screws with diameters greater than M16, as this adjustment has already been incorporated into the capacity factors specified in AS 1720.1.

5.2.1 Procedure 1

The evaluation of characteristic values for strength properties from a sample shall be undertaken in accordance with one of the statistical evaluation methods 1 to 4 described in AS/NZS 4063.2 Appendix B2. For statistical methods 1, 2 and 3, the characteristic value (f_k) for a specific strength property is obtained as the product of the sampling factor (k_s) and the 5th percentile strength (f_{05}) expressed as follows:

$$f_k = k_s \, f_{05} \qquad \text{…Equation 5.3}$$

The equation for calculating values of the sampling factor (k_s) for statistical evaluation methods 1, 2 and 3 takes the following general form:

$$k_s = 1 - \frac{k_z V_R}{\sqrt{n}} \qquad \text{…Equation 5.4}$$

The coefficient of variation of the test data (V_R) shall be calculated from test data but shall not be less than 10%.

Where:

k_s	=	sampling factor
k_z	=	confidence coefficient for estimating the 5th percentile strength with 75% confidence
V_R	=	coefficient of variation of test data
n	=	sample size
S_y	=	Standard deviation of the natural logarithms of the complete test data
f_i	=	i-th ranked strength value in the test data, in megapascals
exp	=	exponential
ln	=	natural logarithm

Method 4 in AS/NZS 4063.2 is based on the method given in ASTM D2915 for evaluation of characteristic values of strength properties from a non-parametric estimate of the 5th percentile value with a stated confidence level. Statistical equations are not required for this method as assumptions are not made about the distributional form of test data.

The following restrictions on minimum sample size, apply to the use of each of these methods:

Table 5.2 Restrictions on minimum sample size for each methods

Method:	Minimum number of specimens required for determination of k_Z:
1: lognormal	for n = 10 & n < 30, use Eqn. 5.9 for n ≥ 30, AS/NZS 4063.2 Clause B2.2.4
2: Weibull tail fit	n ≥ 100
3: non-parametric	n ≥ 30
4: non-parametric (ASTM D2915)	n ≥ 28

Method 1: $$k_z = -0.091\, LN\,(n) + 1.4973 \qquad \text{…Equation 5.9}$$

NOTE 1 The equation for Method 1 (log-normal) is a modification of Clause B2.2 - AS/NZS 4063.1, based on Appendix A, Clause A2 & Table A2 of ISO 12122-1.

NOTE 2 For Method 1, k_z = 1.28 for n= 10.

NOTE 3 An example of data analysis in accordance with AS/NZS 4063.2, using an Excel spreadsheet, is given in Appendix B, for test samples of 10 specimens and 30 specimens respectively.

5.2.2 Procedure 2

This procedure is applicable for sample size n ≤ 30 and the coefficient of variation of strength of the reference population $V_P \leq 40\%$.

The characteristic value for strength R_K shall be given by:

$$R_k = \frac{R_m}{k_t} \qquad \text{…Equation 5.10}$$

Where:

R_m = mean test value of strength
k_t = sampling factor as given in Table 5.3

The coefficient of variation of the reference population (V_P) shall be taken as the coefficient of variation of the test data (V_R), but not less than 10%. This procedure is not applicable when the coefficient of variation of the test data V_R > 40%.

Table 5.3 Sampling factors (k_t) for 5-percentile properties with 75% confidence – lognormal distribution

Sample size (n)	**Coefficient of variation of the reference population (V_P)**			
	10%	20%	30%	40%
10	1.21	1.47	1.80	2.19
20	1.20	1.45	1.77	2.15
30	1.20	1.45	1.74	2.13

Commentary 5.2
The above procedure is a simplified version of Procedure 1 using mean value of the test results with the sampling factor from Wang, C.-H., & Pham, L. 2012. "Sampling factors for prototype testing of structures (Technical Paper)." Australian Journal of Structural Engineering, 12(2), 119-126

Section 7 General Requirements for Reporting

Each test report shall be produced and contain the following information:

(1) The connection configuration and direction of loading (tension or compression) used for testing;

(2) Details of the loading procedure, including the nominal speed of testing (the actual rate of force application for each test will be contained in the data file for each specimen);

(3) Description of the connection member materials including type and size of fastener(s), timber species, wood-based product type, nominal sizes, and material grades;

(4) Method and extent of sampling of materials;

(5) Description of the timber product cross-sectional orientations used for each tested configuration (i.e. bolts positioned perpendicular to the member face or edge), if applicable;

(6) Measured dimensions and geometry for each connection member, including fastener hole diameter and tolerances, end and edge distances for each connection member;

(7) Clear colour photographs of the general testing arrangement and specimens, in a digital format;

(8) Nominal (and where required, measured) properties and dimensions of the fasteners used;

(9) Tabulated summary of the relevant data for each test;

(10) Number of replicate tests;

(11) Any unique / special features that may have some influence on the test procedures and / or results;

(12) Summary statistics for each recorded parameter, including mean, minimum, maximum, and coefficient of variation. In some cases the relationship between test parameters may be required, for example strength and density;

(13) Data analysis as specified in Section 6 of this Standard;

(14) Details of any deviations from the prescribed / standard procedures outlined in these test methods;

(15) For each test specimen, the following information shall be provided (where relevant):

   a. the average density and moisture content of each timber member in the connection,
   b. plotted data of the average load-displacement relationship,
   c. the Design Stiffness,
   d. the Proportional limit load,
   e. the Yield load,
   f. the Maximum load,

g. the Ultimate load,
h. Ductility ratio (if applicable),
i. the Mode of failure,
j. Clear colour photographs of each specimen, noting the unique ID (specimen number), the failure(s), and any other relevant features, in a digital format.

Commentary 7
It is recommended that all measurements be recorded electronically using a suitable data acquisition system, that incorporates time coding. It is recommended that data be recorded at a rate of one reading every 2 to 5 seconds

Appendix A - Guidance on testing large, full-scale or prototype connections (Informative)

The most important consideration for testing of large connection assemblies is to design the test program and set-up arrangements to be able to simulate how a prototype connection system will be required to perform in practice. Full scale testing of connection assemblies or systems, whilst more expensive than testing individual fasteners, not only significantly increases the reliability of an empirical model developed from the test results but also has the potential for optimisation of a connection system to occur, which can in turn reduce the costs when the connection system is standardised and implemented in a structure.

An example of a test set-up for a large prototype moment resisting connection is presented in Figures A1 & A2 below. Key things to note in the photographs are the lateral bracing and reaction frame to maintain stability and in-plane loading, and the location of the instrumentation (LVDT's) to measure expected deformations.

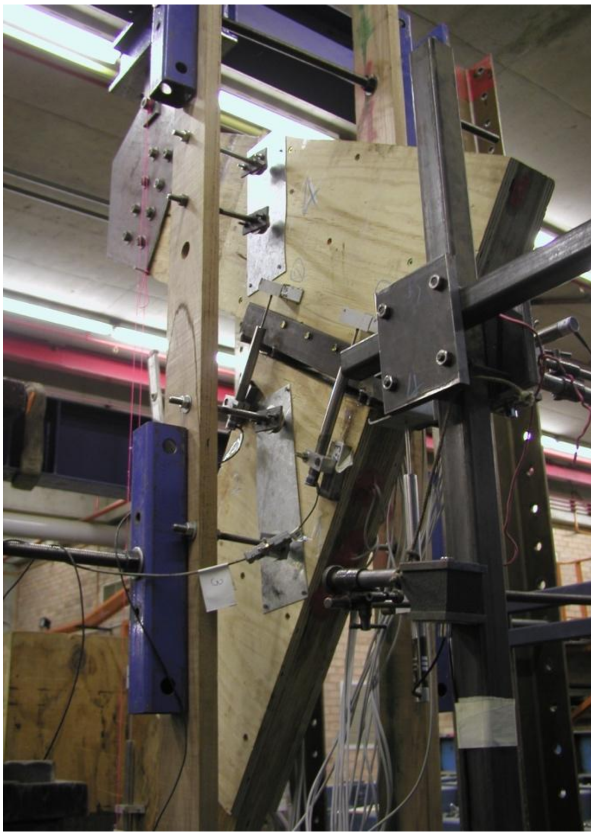


Figure A1 Perspective view

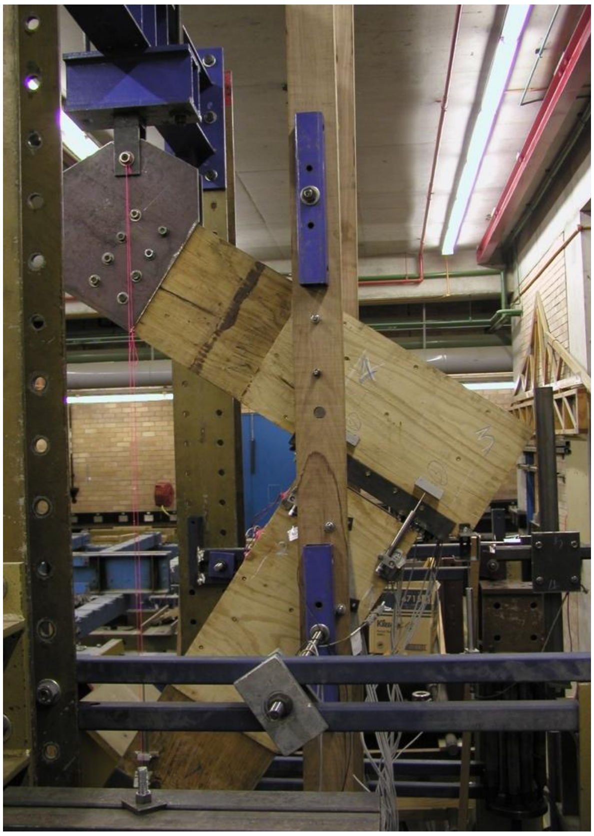


Figure A2 Side view

In situations where full scale, large components or connection assemblies are required to be tested, it is often only possible to test only one, or a limited number of specimens. This creates a specific statistical issue, namely that the characteristic values are to be derived from a very small number of test results, which means that the statistical analysis methods specified in Section 4 cannot be used. It is recommended that ISO 12122-6 should be used is such circumstances to establish characteristic values or design properties with an appropriate level of reliability.

The characteristic value is defined in ISO 12122-6 as an estimate of the property of the reference population with a consistent level of confidence prescribed in the standard. It establishes two methods for the determination of characteristic values:

a) direct calculation from test values;

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

Characteristic values determined in accordance with ISO 12122-6 may be modified to become a design value. This ISO Standard has drawn extensively on analysis methods from Eurocode 0 and has been checked for compatibility with the methods presented in ISO 12122-1 and AS/NZS 4063-2.

ISO 12122-6 Method (a) requires the use of a sampling factor which modifies the test data from a limited number of specimens to fit either a normal or log-normal distribution, in much the same way as is specified for timber in AS/NZS 4063. The more specimens that are tested, the less significant the sampling factor becomes.

ISO 12122-6 Method (b) is particularly applicable to the testing of full-scale prototype connection systems, where it is often impractical to test more than a small number of duplicates, for example two or three specimens. It is the recommended method for use if less than 10 specimens have been tested.

Appendix A of ISO 12122-6 also contains a very useful commentary on testing large connection assemblies, whilst Appendix B presents example calculations using both methods.

Appendix B - Examples of data analysis for a connection assembly (Informative)

This Appendix presents an example of data analysis of a set of tests undertaken on connection assemblies of multiple Type 17 screws in LVL members. The test configuration is shown in the photograph in Figure B1, whilst typical load vs deformation curves are shown in Figure B2.

Stiffness and strength data from a total of 30 tests is presented on the following pages. A randomly selected subset of 10 specimens was then selected for a separate analysis, which is also presented for the purposes of comparison.

Figure B1 Typical connection assembly

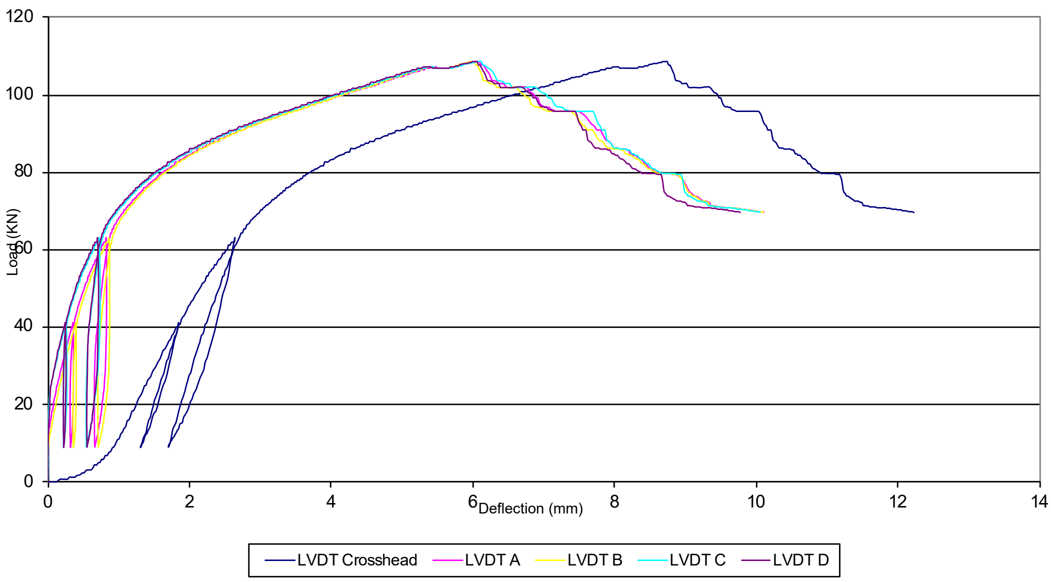


Figure B2 Example of typical Load vs Deformation graph

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B1 Examples Stiffness

Below shows examples of stiffness data.

AS/NZS 4063.2

Sample size	10	
mean	30223	N/mm

note:
Max no. of data points = 800

$E_{(0.05)}$	24549	N/mm
$E_{(0.50)}$	30246	N/mm
mean ln (samples)	10.31	N/mm
stdev	0.12	N/mm
Vr	12.3%	
sampling factor k_s	0.97	
method 1 mean E_k	29424	N/mm
method 2 mean E_k	34117	N/mm

ISO 12122		
kmean,0.75	0.7	
average (sample) =	30223	
STDEV=	3666.45	
COV (sample) =	12.1%	
Xmean,0.75=	29411	N/mm

note: *use Ctrl "A" to clear data*

no of value	Stiffness values	percentile - p(i) $p_i = (i - 0.5)/n$	ln(E)
1	24185	0.050	10.093
2	26967	0.150	10.202
3	27110	0.250	10.208
4	29051	0.350	10.277
5	29779	0.450	10.302
6	30105	0.550	10.312
7	31965	0.650	10.372
8	31987	0.750	10.373
9	35481	0.850	10.477
10	35595	0.950	10.480

Figure B1.1 Example Stiffness 10 samples

AS/NZS 4063.2

Sample size	30	
mean	30230	N/mm

note:
Max no. of data points = 800

$E_{(0.05)}$	24669	N/mm
$E_{(0.50)}$	30237	N/mm
mean ln (samples)	10.31	N/mm
stdev	0.12	N/mm
Vr	12.0%	
sampling factor k_s	0.98	
method 1 mean E_k	29774	N/mm
method 2 mean E_k	34702	N/mm

ISO 12122		
kmean,0.75	0.68	
average (sample) =	30230	
STDEV=	3627.23	
COV (sample) =	12.0%	
Xmean,0.75=	29780	N/mm

note: *use Ctrl "A" to clear data*

no of value	Stiffness values	percentile - p(i) $p_i = (i - 0.5)/n$	ln(E)
1	24629	0.017	10.112
2	25380	0.050	10.142
3	25897	0.083	10.162
4	26042	0.117	10.167
5	26132	0.150	10.171
6	26367	0.183	10.180
7	26753	0.217	10.194
8	26942	0.250	10.201
9	26994	0.283	10.203
10	27630	0.317	10.227
11	27740	0.350	10.231
12	28663	0.383	10.263
13	28711	0.417	10.265
14	29009	0.450	10.275
15	29777	0.483	10.301
16	30564	0.517	10.328
17	30906	0.550	10.339
18	31267	0.583	10.350
19	31690	0.617	10.364
20	31911	0.650	10.371
21	32440	0.683	10.387
22	32733	0.717	10.396
23	32810	0.750	10.398
24	33172	0.783	10.409
25	33269	0.817	10.412
26	34789	0.850	10.457
27	35409	0.883	10.475
28	35789	0.917	10.485
29	36601	0.950	10.508
30	36896	0.983	10.516

Figure B1.2 Example Stiffness 30 samples

B2 Examples - Strength

Below shows examples of strength.

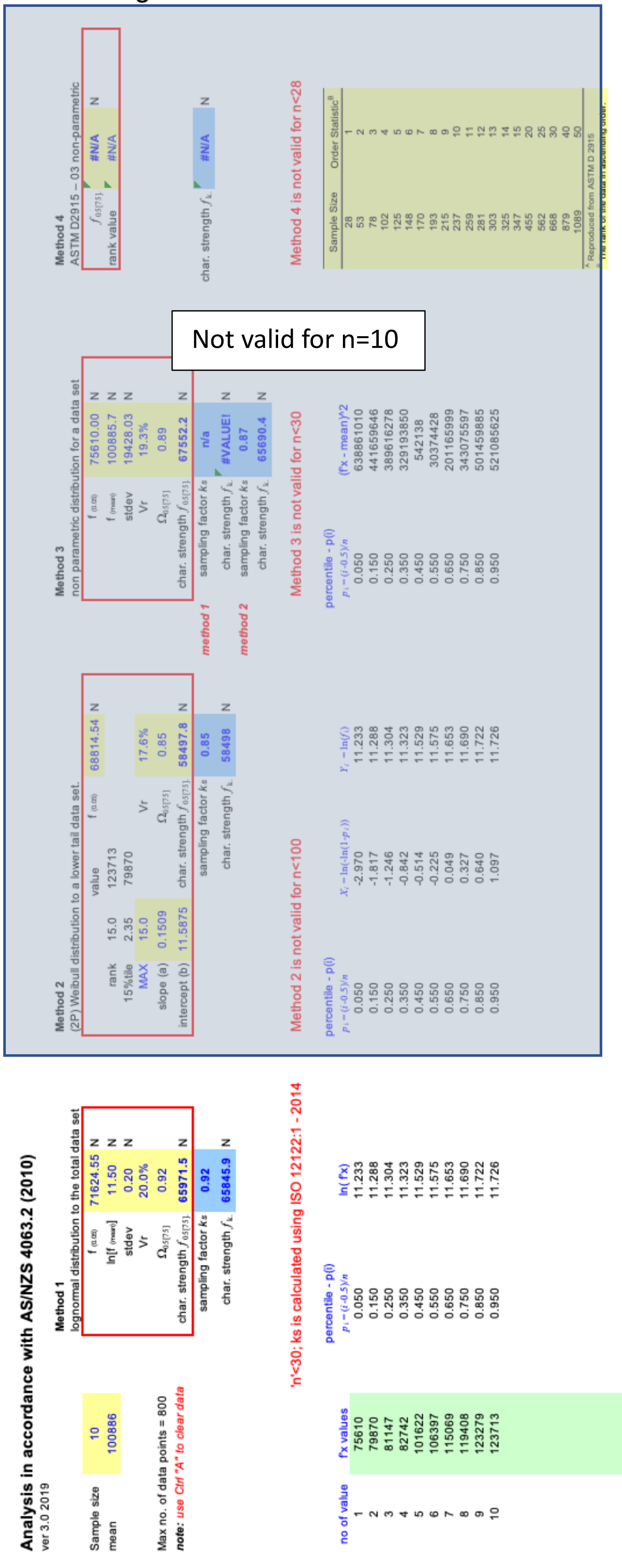

Figure B2.1 Examples Strength

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Analysis in accordance with AS/NZS 4063.2 (2010)

ver 3.0 2019

Sample size	30
mean	100903

Max no. of data points = 800

note: *use Ctrl "A" to clear data*

Method 1
lognormal distribution to the total data set

$f_{(0.05)}$	77953.65	N
$\ln[f_{(mean)}]$	11.51	N
stdev	0.15	N
Vr	15.1%	
$\Omega_{05[75]}$	0.97	
char. strength $f_{05[75]}$	75266.0	N
sampling factor k_s	0.97	
char. strength f_k	75481.0	N

Method 2
(2P) Weibull distribution to a lower tail data set.

		value			
rank	15.0	98402	$f_{(0.05)}$	80443.07	N
15%tile	5.35	84048			
MAX	15.0		Vr	7.4%	
slope (a)	0.0589		$\Omega_{05[75]}$	0.96	
intercept (b)	11.4703		char. strength $f_{05[75]}$	77513.4	N
			sampling factor k_s	0.96	
			char. strength f_k	77513	N

Method 3
non parametric distribution for a data set

	$f_{(0.05)}$	81284.27	N
	$f_{(mean)}$	100903.2	N
	stdev	15226.87	N
	Vr	15.1%	
	$\Omega_{05[75]}$	0.95	
	char. strength $f_{05[75]}$	77365.1	N
method 1	sampling factor k_s	n/a	
	char. strength f_k	#VALUE!	N
method 2	sampling factor k_s	0.94	
	char. strength f_k	76786.8	N

Method 4
ASTM D2915 – 03 non-parametric

$f_{05[75]}$	78102.0	N
rank value	1	
char. strength f_k	78102.0	N

ks is calculated using AS/NZS 4063.2

Method 2 is not valid fo

Not valid for n=30

OK, n>=30

OK, n>=28

no of value	f'x values	percentile - p(i) $p_i=(i-0.5)/n$	ln(f'x)	percentile - p(i) $p_i=(i-0.5)/n$	X_i … $(p_i))$	$Y_i=\ln(f_i)$	percentile - p(i) $p_i=(i-0.5)/n$	(f'x - mean)^2
1	78102	0.017	11.266	0.017		11.266	0.017	519896242
2	81394	0.050	11.307	0.050		11.307	0.050	380610185
3	81530	0.083	11.309	0.083		11.309	0.083	375322170
4	83809	0.117	11.336	0.117		11.336	0.117	292212813
5	84048	0.150	11.339	0.150		11.339	0.150	284098891
6	84928	0.183	11.350	0.183		11.350	0.183	255208080
7	87078	0.217	11.375	0.217		11.375	0.217	191137077
8	87182	0.250	11.376	0.250		11.376	0.250	188272244
9	87256	0.283	11.377	0.283		11.377	0.283	186246978
10	88261	0.317	11.388	0.317		11.388	0.317	159826064
11	90300	0.350	11.411	0.350	-0.842	11.411	0.350	112428557
12	95126	0.383	11.463	0.383	-0.727	11.463	0.383	33376425
13	96366	0.417	11.476	0.417	-0.618	11.476	0.417	20586486
14	97901	0.450	11.492	0.450	-0.514	11.492	0.450	9013405
15	98402	0.483	11.497	0.483	-0.415	11.497	0.483	6256168
16	98710	0.517	11.500	0.517	-0.319	11.500	0.517	4810272
17	102124	0.550	11.534	0.550	-0.225	11.534	0.550	1490271
18	103041	0.583	11.543	0.583	-0.133	11.543	0.583	4570046
19	103248	0.617	11.545	0.617	-0.042	11.545	0.617	5497931
20	104732	0.650	11.559	0.650	0.049	11.559	0.650	14659454
21	109408	0.683	11.603	0.683	0.140	11.603	0.683	72331056
22	112675	0.717	11.632	0.717	0.232	11.632	0.717	138574490
23	113328	0.750	11.638	0.750	0.327	11.638	0.750	154374827
24	120190	0.783	11.697	0.783	0.425	11.697	0.783	371979368
25	120918	0.817	11.703	0.817	0.529	11.703	0.817	400590885
26	121979	0.850	11.712	0.850	0.640	11.712	0.850	444187941
27	122514	0.883	11.716	0.883	0.765	11.716	0.883	467025236
28	122763	0.917	11.718	0.917	0.910	11.718	0.917	477849399
29	124383	0.950	11.731	0.950	1.097	11.731	0.950	551299443
30	125401	0.983	11.739	0.983	1.410	11.739	0.983	600140572

Sample Size	Order Statistic[B]
28	1
53	2
78	3
102	4
125	5
148	6
170	7
193	8
215	9
237	10
259	11
281	12
303	13
325	14
347	15
455	20
562	25
668	30
879	40
1089	50

[A] Reproduced from ASTM D 2915
[B] The rank of the data in ascending order.

Figure B2.2 Examples Strength

B3 Background to analysis methods for the testing of timber connections

Characteristic values from test results on a sample from a defined reference population can be analysed using AS/NZS 4063.2. For timber connections, with number of test sample n less than 30, both FWPA (for Category A & B) and AEFAC (for Category C & D) specify characteristic values with 75% confidence for

(a) Mean value of stiffness

(b) 5-percentile value of strength

For lognormal distribution, these values can be derived as a function of the mean values that can be obtained from test data using the simple format

Characteristic value $X_c = \frac{Mean\ test\ value\ X_M}{k}$

Where k is the sampling factor = k_m for stiffness or k_s for strength, corresponding to the above definitions.

This paper shows how these sampling factors can be derived based on the observation that for a reference population with coefficient of variation V_R, the population of n samples will have a coefficient of variation of $\frac{V_R}{\sqrt{n}}$

Derivation of sampling factor for stiffness k_m

Characteristic value for stiffness E_k is given by: $E_k = \frac{E_m}{k_m}$

Where E_m is the mean test value of stiffness assumed to be approximately the same as that of the reference population and K_m is the sampling factor to raise the level of confidence to 75%.

The CDF for a lognormal distribution with a mean value X_M and a coefficient of variation V_R is

$Fx = \Phi\{(\ln x - \xi)/q\}$ Equation B3.1

With $q^2 = \ln(V_R{}^2 + 1)$ and $\xi = \ln(X_M) - q^2/2$

Hence $\ln(x) = q.\ \Phi^{-1}(Fx) + \xi$ and $x = \exp(q.\ \Phi^{-1}(F_X) + \xi)$

For 75% confidence level $F_X = 0.75$, thus for a sample of 1 (n=1) the value of K_m (=x) is a function of V_R, as given in Table B3.1.

Table B3.1 Value of k_m for 75% confidence for n=1

Coefficient of Variation	q	ξ	K_m (=exp (q. Φ^{-1}(0.75) + ξ)
0.10	0.0998	-0.0050	1.064
0.20	0.1980	-0.0196	1.121
0.30	0.2936	-0.0431	1.167
0.40	0.3852	-0.0742	1.204

For a reference population of mean X_M with a coefficient of variation V_R, a sample size of n will have a mean $X_{MN} = \frac{(\Sigma x_i)}{N} \approx X_M$ and a coefficient of variation $V_N = \frac{V_R}{\sqrt{n}}$ Thus, for a population of sample size n, the coefficient of variation and the corresponding values of q and ξ should be adjusted accordingly for the calculation of k_m. These are shown in Table B3.2 for *n* = 1, 5, 10, 20, 30 and V_R =0.1, 0.2, 0.3, 0.4.

Table B3.2 Sampling factors k_m for mean-based properties with 75% confidence – lognormal distribution

Sample size (n)	Coefficient of variation of the reference population			
	10%	20%	30%	40%
10	1.02	1.04	1.06	1.08
20	1.01	1.03	1.04	1.06
30	1.01	1.02	1.04	1.05

Derivation of sampling factor for strength k_s

Characteristic value for strength R_k is given by $R_k = \frac{R_m}{k_s}$

Where R_m is the mean test value of strength assumed to be approximately the same as that of the reference population and k_s is the sampling factor to raise value to 5-percentile value and the level of confidence to 75%.

The ratio of the mean value R_m to the 5-percentile value R_{05} is $R_{05} = \frac{R_m}{k_{05}}$.

This can be calculated for any reference population of coefficient of variation V_R using Eq. B3.1 with F_X = 0.05 x k_{05} is presented in Table B3.3.

Table B3.3 Value of k_{05} for 75% confidence for *n* = 1

Coefficient of variation	0.10	0.20	0.30	0.40
k_{05}	1.1841	1.4124	1.6920	2.0230

The sampling factor for strength $k_s = k_m k_{05}$. This is presented in Table B3.4.

Table B3.4 Sampling factors k_s for mean-based properties with 75% confidence – lognormal distribution

Sample size n	Coefficient of variation of the reference population			
	10%	20%	30%	40%
10	1.21	1.47	1.80	2.19
20	1.20	1.45	1.77	2.15
30	1.20	1.45	1.75	2.13

Worked Examples

The worked examples are taken from FPWA Report 4 Industry standard – Methods of test for mechanical fasteners and connectors Part 1: Category A&B Fasteners.

Mean-based properties

Number of samples *n* = 10 Test mean value of stiffness E_m = 30,223 N/mm

Test coefficient of variation V_t = 0.12

For comparison purposes, the test coefficient of variation will be taken as representative of the reference population.

For lognormal distribution:

k_m = 1.025 (interpolated from Table B3.2)

Characteristic value of stiffness E_k = 29,485 N/mm

AS 4063.2 method E_k = 29,424 N/mm ISO 12122 method E_k = 29,411 N/mm

The coefficient of variation should be the estimated coefficient of variation of the reference population and in general should be greater than the coefficient of variation of the test samples.

5-percentile based properties

Number of samples n = 10 Test mean value R_m = 1,000,886 N/mm^2

Test coefficient of variation V_t = 0.20

For comparison purposes, the test coefficient of variation will be taken as representative of the reference population.

For lognormal distribution:

Procedure 1 – Method 1 (AS/NZS 4063.2) R_k= 65,846 N/mm^2

Procedure 2 k_s = 1.47 Characteristic value R_k = 68,629 N/mm^2

The coefficient of variation should be the estimated coefficient of variation of the reference population and in general should be greater than the coefficient of variation of the test samples.

B4 Pooled data

It may be desirable to combine two or more species into a single marketing group, for example a Joint Group. When this is done it is necessary to determine the characteristic values for the combined pooled data. There are no limitations as to how many data subsets can be combined to form pooled data. Test data from a number of different test programs can be pooled to increase the size of the sample. However, the data should be standardised and sufficient information on the standardization models should be provided in the test report to enable comparisons with other standardization models. Guidance and examples on pooling of data for connection tests is given in AS/NZS 4063.2 (Section 3.3.3 & Appendix D) and ISO 12122-1.

Appendix C - General considerations for non-standard conditions (Informative)

Adapted from Appendix C, AS1649 (2025)

C1 Duration of loading

Characteristic capacities derived from the results of short-duration tests in accordance with Sections 3 & 4 are intended to be applied in AS1720.1 for design of connections that will normally be subjected to long-duration loading conditions (dead load). Based on past experience, it is believed these basic loads will generally be somewhat on the conservative side. Therefore, they may be modified by information from adequately replicated and properly controlled long-duration testing.

Long-duration testing of joints is extremely desirable and, with new types of fasteners, is essential in order to establish the real practical value and a true measure of the serviceability of a particular kind of fastener. As at 2018, the authors are not aware of any methods of test that would significantly reduce the time scale for long-duration testing. Therefore, care should be taken in interpreting the results of short-duration tests, the results from which are used to provide the basis for the design of permanent structures.

When a joint is subjected to impact either normally or by chance, the load effect can be increased significantly, resulting in possible effects on the fastener and the timber elements. If there is any doubt of the impact resistance of a fastener when built into a joint, it should be subjected to a special series of tests to determine the limiting impact resistance of joints with test procedures similar in all respects to those specified in Section 3 of this Standard.

C2 Fastener spacing

The characteristic capacities derived in accordance with Sections 3 & 4 are applicable in design for edge and end-distances, i.e. the fastener spacing relative to the end and edges of each member, no less than those used in the tests from which the capacities were derived. It should not be assumed that any increase in one or other of the fastener spacings would result in an increase in the characteristic capacity. Therefore, no such increase should be made unless justified on the basis of further tests, conducted generally in accordance with the provisions of this Standard. Further testing is similarly required to establish characteristic capacities for joints with end and/or edge distances smaller than those used in the standard tests.

C3 Timber dimensions

The characteristic capacities derived in accordance with Sections 3 & 4 are applicable for joints in which the member widths and thicknesses are no less than those used in the tests from which the capacities were derived. For timber dimensions differing from those used in the standard tests, conditions similar to those mentioned in Paragraph D2 should apply for other fastener spacings.

C4 Angle of grain

The results of tests conducted in accordance with Sections 2 & 3 provide characteristic capacities for joints in which all members are forced in a direction parallel to the grain direction and also for joints in which one member is forced at right angles to the grain direction. Generally, the characteristic capacities for these two-grain orientations will differ significantly, with that for the “parallel to grain” loading exceeding the “perpendicular to grain” loading. Characteristic capacities for other grain orientations should be obtained from adequately replicated tests or should be estimated by:

(a) linear interpolation, if the basic load parallel to the grain does not exceed the characteristic capacity perpendicular to the grain by more than 50%; or

(b) the use of Hankinson's formula (as noted in Equation 4.4.1 of AS1720.1 – 2010) if the characteristic capacity parallel to the grain is more than 50% greater than the characteristic capacity perpendicular to the grain.

C5 Single and double shear

The characteristic capacities for Category A fasteners subjected to lateral loading as derived from testing in accordance with Section 3, are generally applicable to fasteners loaded in single shear. Where the fastener is by its very nature capable of being loaded in double shear, as is the case with relatively long nails and screws, the characteristic capacity may be doubled when the fastener is so used. If any doubt exists as to the capacity of the fastener in double shear, a series of adequately replicated tests should be carried out on the fastener loaded in this manner. All Category B fasteners tested in accordance with Section 3 are loaded in double shear.

C6 Metal connection plates

With several types of fasteners, the outer joint members in a three-member joint or one of the members of a two-member joint may be replaced by steel members. In other cases, a slotted steel plate (or several plates) may be inserted within the timber members as shown in Figure D1 to create a three-member joint. A series of tests on joints of this type of construction should be conducted to determine whether an increase in the characteristic capacity derived from tests on all timber joints is justified.

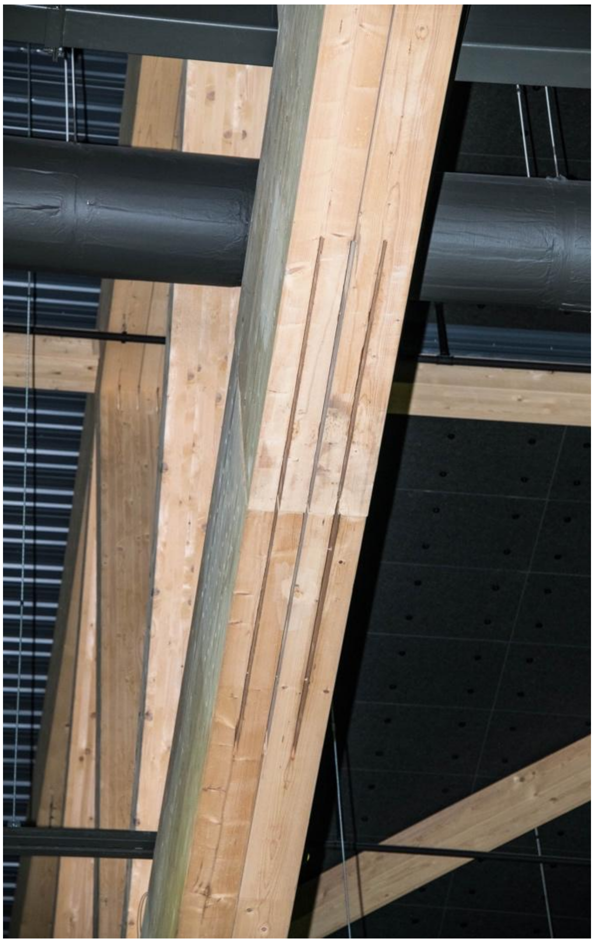


Figure C1(a) Slotted plate tension connection

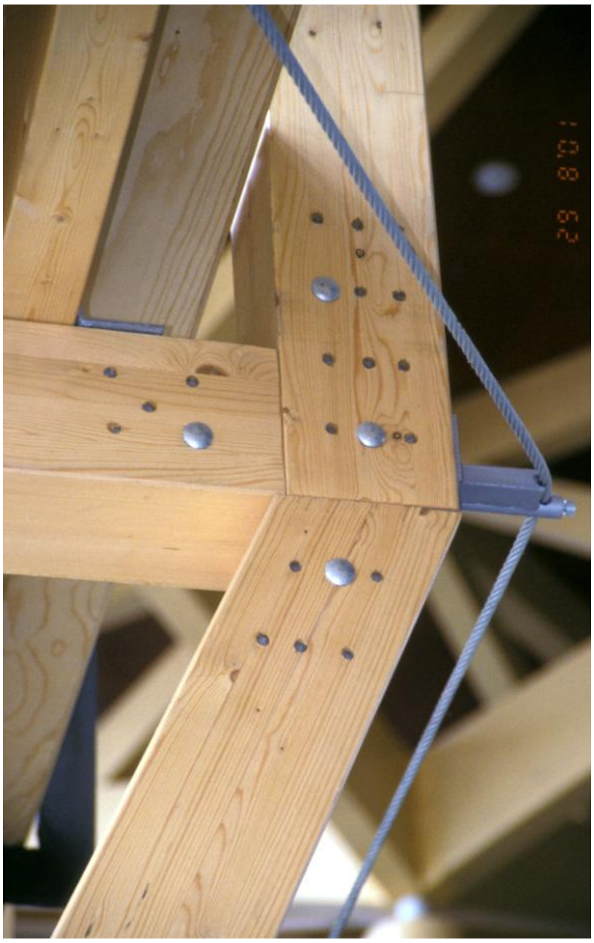


Figure C1(b) Concealed slotted plate connection

Investigation into numerous failures of timber structures in Europe (Kohler, Fink and Toratti, 2011), has revealed that end splitting of the timber members can occur when shrinkage of the timber is hindered due to restraint effects of slotted steel plates using multiple dowel fasteners, when no allowance has been made for the shrinkage to occur. of a two-member joint may be replaced by steel members.

C7 Multiple fasteners

The characteristic capacities for laterally loaded fasteners, as derived from tests conducted in accordance with Sections 3 & 4, are applicable only for a single fastener acting at any one timber fastener interface. There is ample evidence to show that, for two or more fasteners acting in parallel in transferring load from one joint member to an adjacent member, the total load, which several fasteners acting together can carry, is significantly less than the sum of the loads for the fasteners acting separately as single units. This difference in performance is particularly important for tension connections or when unseasoned timber is used for the joint members.

Such recommendations as may be given for design loads for multiple fasteners, e.g. in AS 1720.1, should be conservative, unless a specific “prototype” connection system is being characterised. These recommendations may therefore be modified by information from adequately replicated and properly designed tests to establish a suitable factor or factors by which the characteristic capacity for a fastener should be modified to provide a design load for two or more fasteners acting together.

C8 Combinations of materials

For some timbers in common use, it may be commercially practicable to impose a lower density limit for structural material. As the strength of joints made with mechanical fasteners tends to increase with timber density, higher working loads for fasteners are to be expected if low-density material is excluded from a species by specification.

Characteristic capacities for a particular fastener higher than those determined for the species as a whole or for the strength group in which the species is classified are permitted provided that:

(a) the sampling of the timber for joint testing in accordance with this Standard is conducted so as to exclude material of density lower than some given value; and

(b) the characteristic capacities derived from such tests are stated as applying only to material of a density higher than that used as a lower limit in the test material.

C9 Duration of loading

It is possible to require connections for building systems that utilise different Engineered Wood Products in combination, (such as GLT, CLT and LVL) to form particular structural joint assemblies. The structural performance of these connection systems where the product (GLT, CLT, LVL) used from more than one grade or species of timber, has a high probability of being limited by the least dense EWP / timber component in the assembly and as such, use of code models for predicting the capacity of the connection(s) will not be valid. It is recommended that full scale testing of such connection systems be undertaken to quantify performance and reduce risk of non-performance and unconservative design.

Appendix D - Modified Loading Regime (Informative)

As noted in Clause 2.2.2, preloading to 0.4 x F_{est} is not considered necessary, since any initial slip has to be taken into account for determination of both the stiffness of the connection and the yield point, using an offset equal to 5% of the fastener diameter. Furthermore, testing of 260 MGP (pine) bolted connection assemblies confirmed that most initial slip or "looseness" occurred between loads of 5kN to 10kN, after which the slope of the load vs deformation curve (or actual connection stiffness) is constant until the onset of non-linear behaviour. This change point was usually less than 0.2 x F_{est}. This observation is illustrated in the Figures below for a 3-member compression joint with 2xM2 bolts in 35mm thick MGP 12.

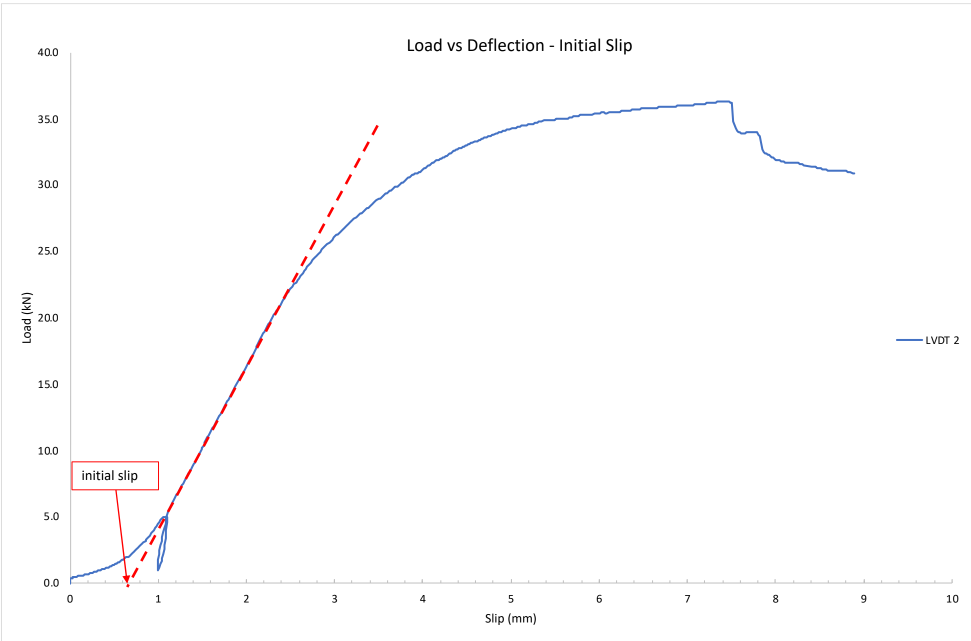


Figure D1 – Plot of Load vs. Deformation – the red line indicates the true stiffness

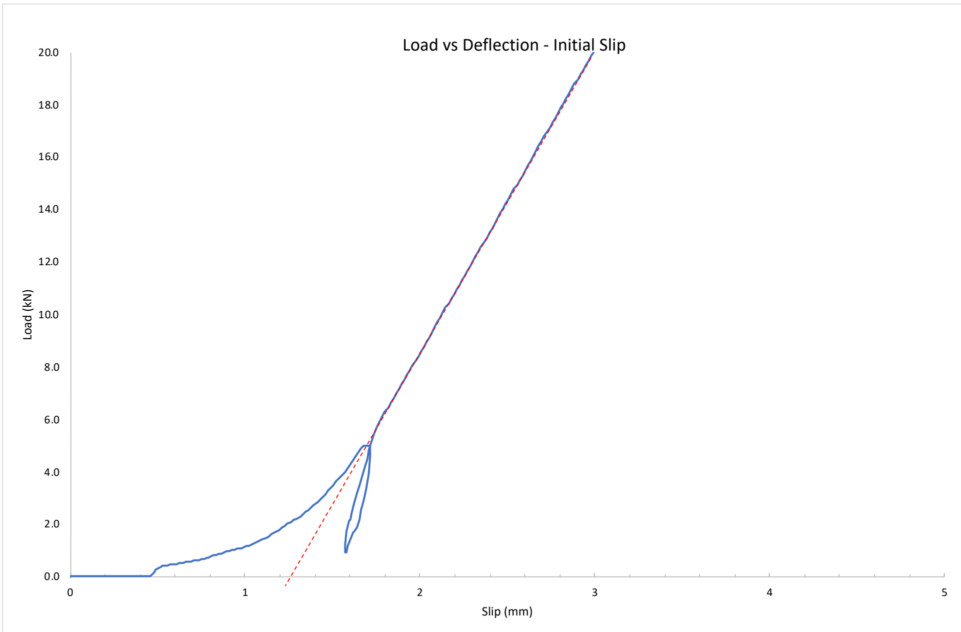


Figure D2 Intersection of the slope line and the x-axis indicates the amount of initial slip

Figure D2, indicates that:

1) Unloading and reloading (at 5kN in this case or approx. 0.15 x F_{est}) is not necessary to determine the actual design stiffness of the connection and is not required to determine the amount of initial slip.

2) The initial stiffness up to the onset of linear behaviour is not relevant.

3) The amount of initial slip is determined by extending the slope line to intersect with the x-axis.

4) The offset to determine F_y is based on the actual slope (stiffness), as seen in Figure D3. should be measured by placing the piece so that three of the corners of one face are in contact with a flat surface and measuring the perpendicular distance from the fourth corner to the flat surface (see Figure A2.3).

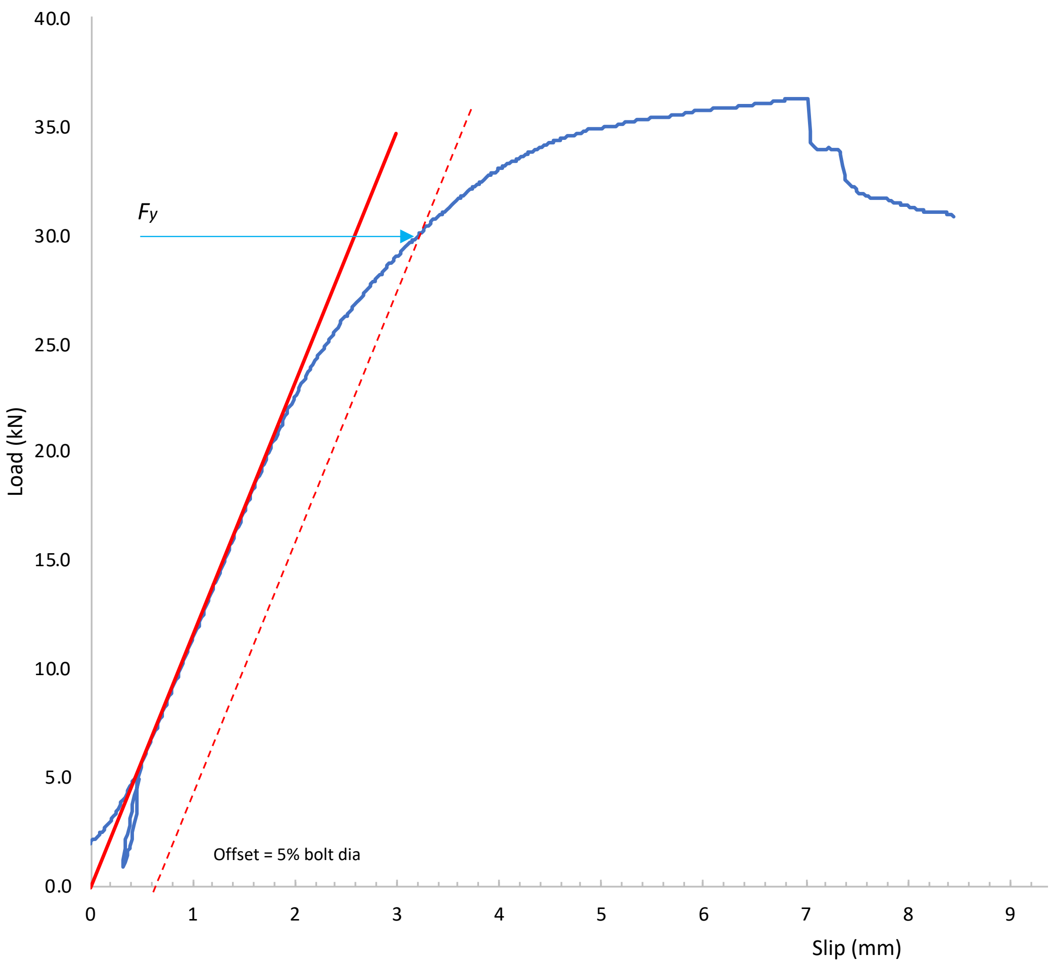
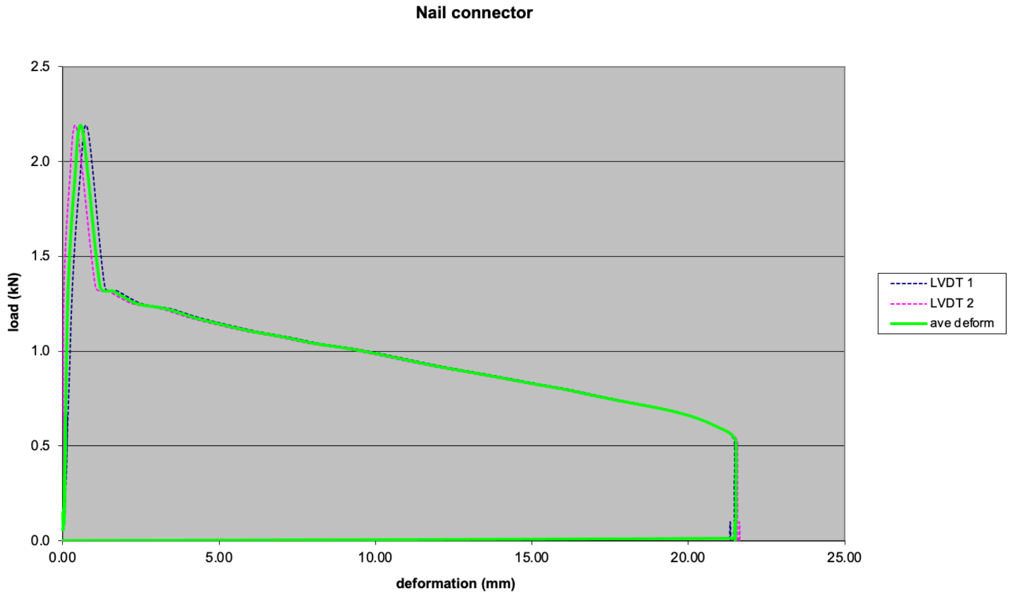


Figure D3 Load vs Deformation curve corrected for initial slip, with offset to determine F_y.

Appendix E - Typical loading curves in withdrawal (Informative)

The load vs. deformation curves for both nails and screws in withdrawal are usually significantly different from those observed when the same fasteners are subjected to lateral loading. Typically, the load increases with a very small amount of deformation or relative movement between the fastener and the timber specimen until a peak value is reached, after which there is usually a sudden drop in load as the fastener either slips in the hole and / or localised deformation occurs in the wood adjoining the fastener. Examples of this phenomenon are show in Figures E1 & E2.



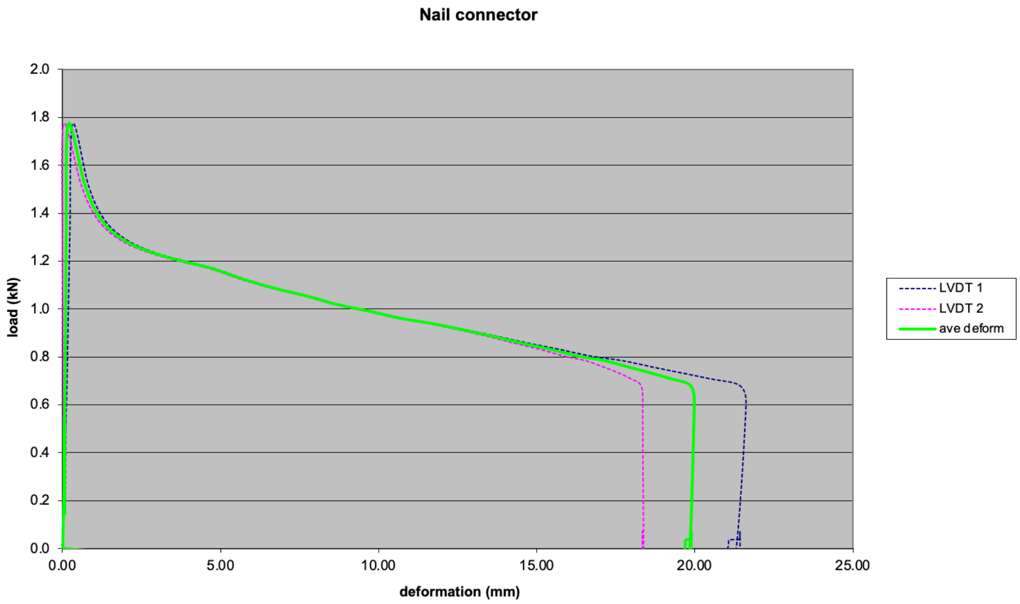


Figure E1 – Typical Load vs Deformation curves for nails

Figure E2 – Typical Load vs Deformation curves for screws

Appendix F - Typical Test setups (Informative)

This Appendix documents the procedures undertaken for a “typical” test of a 3-member connection assembly. This particular test was undertaken as part of a pilot study to validate the test procedures in this Standard.

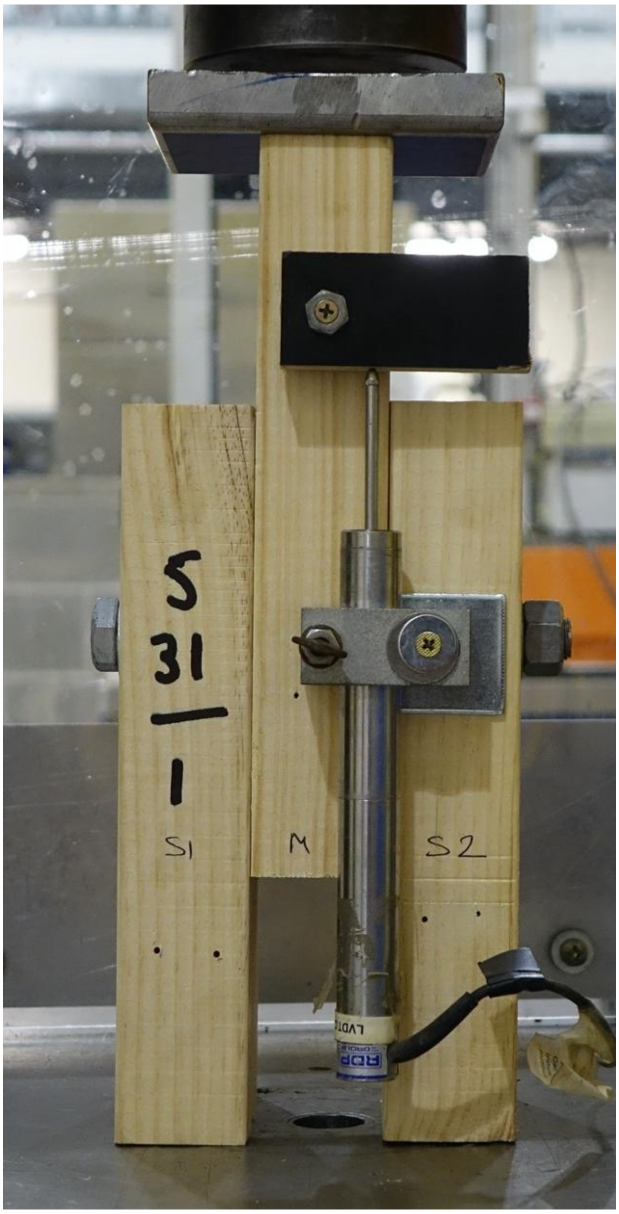


Figure F1: typical 3-member compression specimen

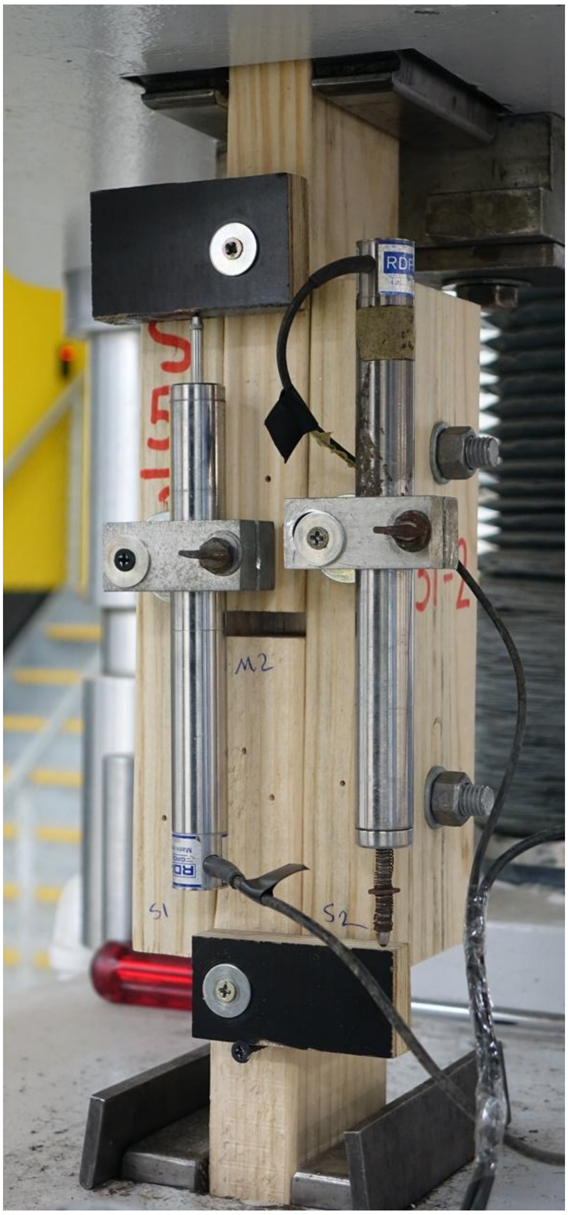


Figure F2: typical 3-member tension specimen

The process for undertaking testing is follows:

1.Select and prepare specimens for the relevant series to be tested.

2.Label each specimen with the correct series number and the sequence number of the specimen. For example; Figure 2 shows test series 31, specimen number 1.

3.Install each specimen in the universal testing machine (UTM).

4.Attach the LVDT(s) and reaction plate(s) as shown in Figures F1 & F2.

5.Check that the acquisition system is operating correctly to monitor and record measurements of load, loading head movement (stroke) and LVDT(s) at a recording rate of one reading every 2 seconds. Also check that the name of the data file created to record the measurements, is unique and the same as that of the specimen ID.

6.Ensure that the digital camera being used, has been configured to note the correct date and time on each image (this was overlooked for the UTS tests).

7.Photograph each specimen in the UTM prior to commencing testing, clearly showing the specimen ID.

8.Commence loading the specimen at a suitable rate, as specified in the Testing Procedures. However, the loading rate of 1mm per minute noted in Clause 2.2.3 was found to be too slow and subsequently, the optimal loading rate used in the pilot program was deemed to be 2.5mm / minute for both compression and tension testing.

NOTE 1 The acquisition software should be capable of charting load vs deflections in real time. (The UTM and acquisition system used in a project for compression tests are shown in Figure H3. A similar system was used for undertaking the tension tests).

NOTE 2 Digital image correlation can be used in some cases to measure full-field displacement and strains. However, care should be taken when the sample fails due to brittle failure or fracture. It is recommended, that if DIC is used, LVDT measurements are also recorded.

Figure F3 – Photographs of UTM and acquisition system used for compression test

Appendix G - Background Standards (Informative)

The determination of the fundamental material properties for use with the European Yield Model equations (as specified in AS1720.1) should be undertaken in accordance with the following Standards:

AS / NZS ISO 10984-1: Determination of yield moment of fasteners, and

AS / NZS ISO 10984-2: Determination of Embedding strength

AS / NZS ISO 10984-1 specifies two test methods; Method A is a 4-point bending test (based on EN 409), whilst Method B is a 3-point testing arrangement (based on ASTM F1575).

AS / NZS ISO 10984-2 is based upon EN 383 and ASTM D5764. Loading may be applied either in tension or compression, although the apparatus and setup for tension testing is more complex than that for compression. Measurement of the cross-head movement is acceptable for recording the embedment of the fastener in the wood foundation when the testing is based upon compression loading, which also simplifies the test set up, and as such, compression testing is the recommended test method.

NOTE Method B (based on ASTM F1575) is preferred by many testing organisations, mainly due to its simplicity and should be done as half hole to prevent bending of fastener for engineered timber. However, it should be noted that the Preface of AS/NZS/ISO 10984-1 recommends Method A (the EN 409 method), but this requirement is not Normative.

Appendix H - Combined resistance for Joints - General Requirements (Informative)

H1 Introduction

Typical examples of joints where the connectors are loaded axially (in either tension or compression) and laterally in shear are shown in Figure H1(a), (b) & (c).

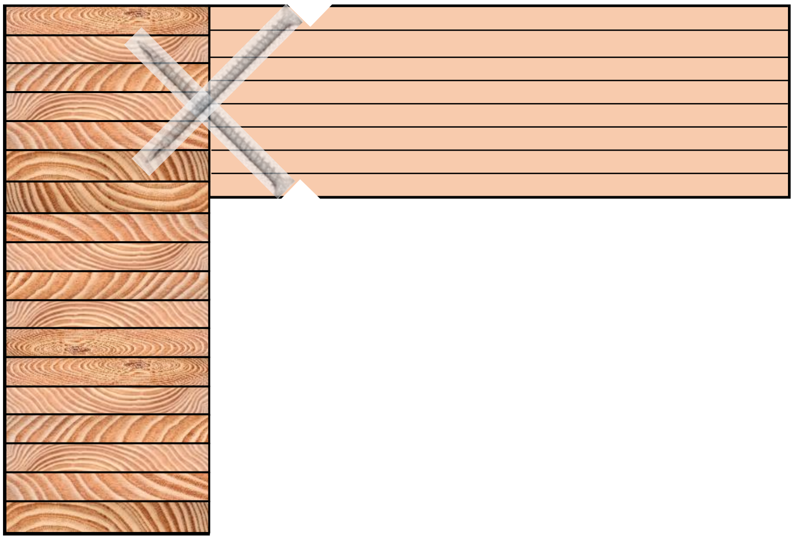


Figure H1(a) double inclined screws (beam or floor to beam)

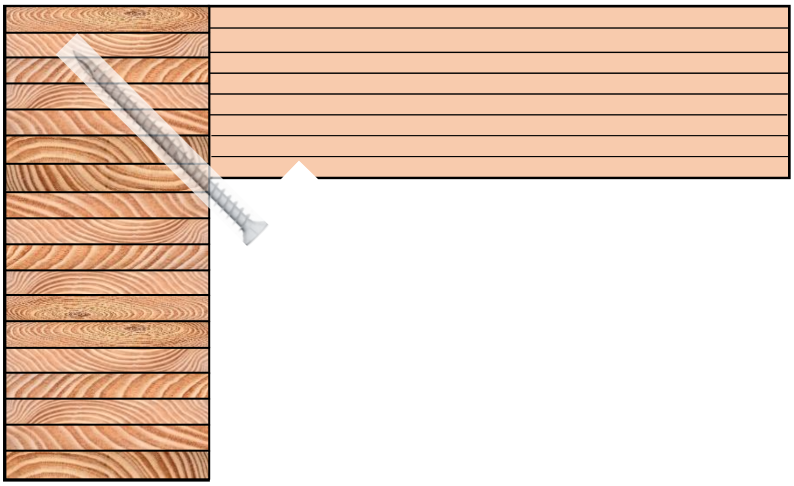


Figure H1(b) single inclined screws (beam or floor to beam)

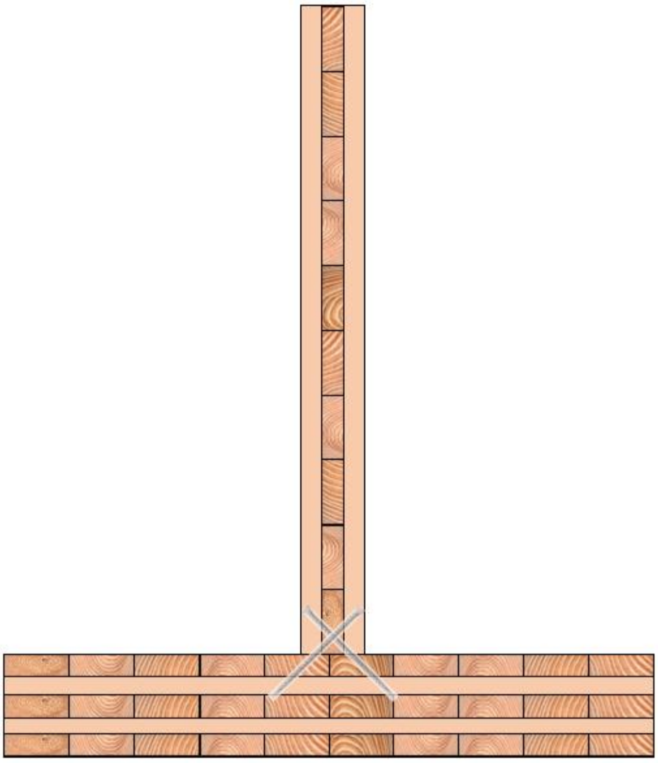


Figure H1(c) double inclined screws (wall to floor)

H2 Test specimens

The test specimens should be manufactured to be representative of the ones used in practice, with such thickness as to allow the fastener to be driven to the correct depth without complete penetration of the specimen.

NOTE Generally, the types of screws used are propriety items and installation, including angles of inclination, spacing, edge and end distances should be in accordance with the manufacturer's specifications. Other dimensions should be such that distances between the fastener and the edges and ends of the specimen should be sufficient for correct performance of the fastener and so that splitting will not occur.

H3 Loading Protocol

The load should be increased until failure occurs. Specific requirements of the test procedure for fasteners subject to withdrawal and lateral shear are specified in Section I.

NOTE For the purposes of this Standard, the test method to determine the capacity of a fastener or connection assembly subject to lateral shear and axial withdrawal, is similar to the modified loading procedure, shown in Figure H1(b). A typical load vs. deformation curve for testing in withdrawal, is presented in Figure H2.

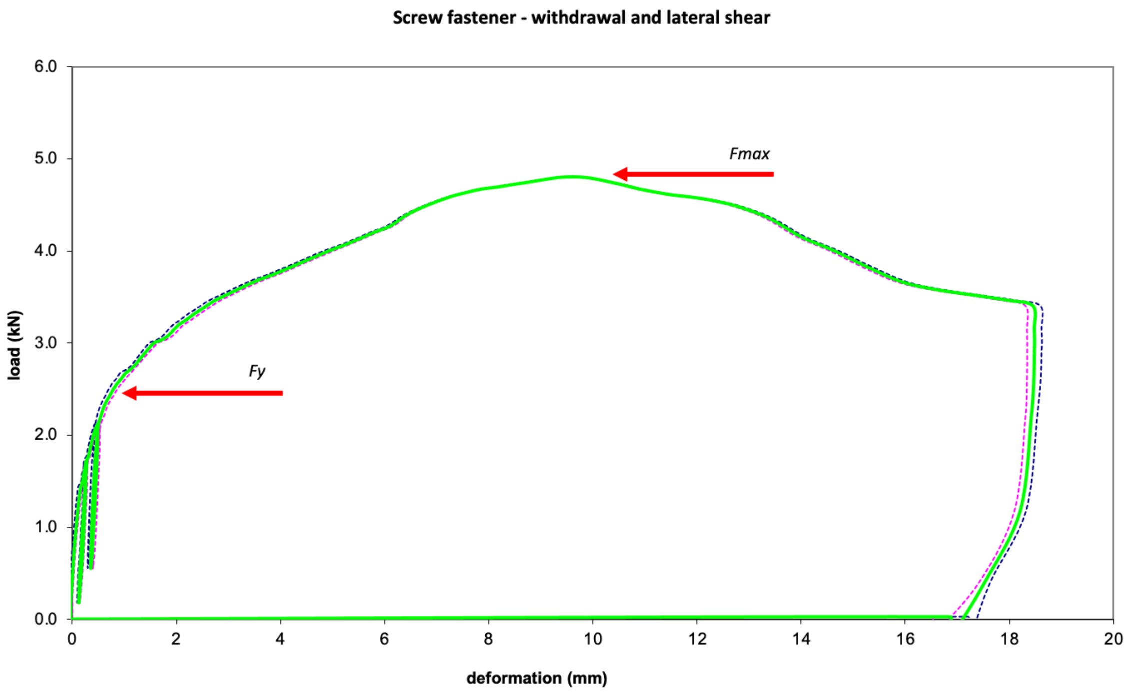


Figure H2 Typical (idealised) Load and Deformation curve for withdrawal & lateral shear (based on the ISO loading procedure, including unloading cycles)

Appendix I - Specific Requirements for Combined Axial & Shear Tests (Informative)

This Section describes the procedures for undertaking testing of specific joints and connection assemblies, in accordance with the general provisions of Appendix H for combined action loading of lateral shear and axial loads. This includes testing procedures that should be undertaken in order to derive the relevant design properties for use with AS 1720.1.

I1 Test Details for Connection Assemblies

Schematic details of the test assemblies for screwed connections are shown below in Figure I1 for beam to beam connections, and Figure I2 for floor to wall connections.

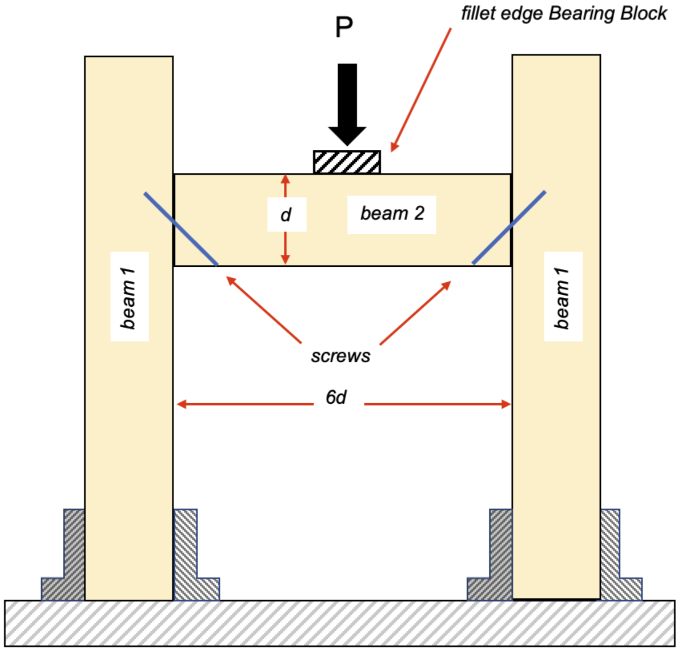


Figure I1 typical beam to beam connection assembly.

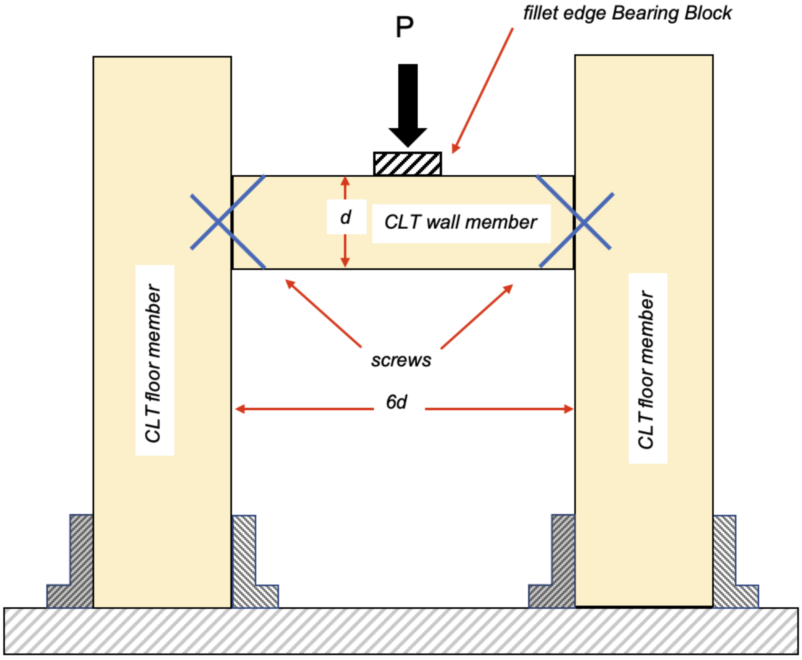


Figure I2 typical wall to floor connection assembly

The specimen should be clamped and firmly supported to the platen of the test machine so the bottom of the vertical members are restrained on the platen as the load is applied.

LVDT's should also be used to record any horizontal movement at the tops of the vertical members. The maximum load (P_{max} or F_{max}) of each test should be noted.

I2 Alternate method for determining capacity of inclined screws (informative)

In theory it is possible to estimate the capacity of inclined screws by undertaking separate shear tests in accordance with Section 3 and withdrawal tests in accordance with Section 4, and then using Hankinson's formula (refer: AS 1720.1 Section 4.4.2.4, Equation 4.4 (1)) to predict the shear capacity and the withdrawal capacity at any given angle of inclination. However, wherever possible, it is recommended that full scale tests be undertaken as noted in Appendix H and I.

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ASTM D2915 Standard Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

ASTM D5652 Standard Test Methods for Single-Bolt Connections in Wood and Wood-Based Products

ASTM E2126 Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings

ASTM E5750 Standard Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies

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FWPA Standards Writing Committee

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SPAX Pacific

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TGA Engineers

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Timber Queensland Ltd