TIMBER FASTENING TECHNICAL NOTE

Australian Engineered Fasteners and Anchors Council

AEFAC – TFTN02

TESTING AND EVALUATION OF TIMBER-TO-COLD-FORMED STEEL CONNECTIONS

Version 1.0
22 August 2023

1. Scope

This Technical Note provides guidance for the testing and evaluation of timber-to-cold-formed steel (CFS) connections.

An overview of current Australian standards and guides for the testing and evaluation of timber-to-timber and CFS-to-CFS connections is provided.

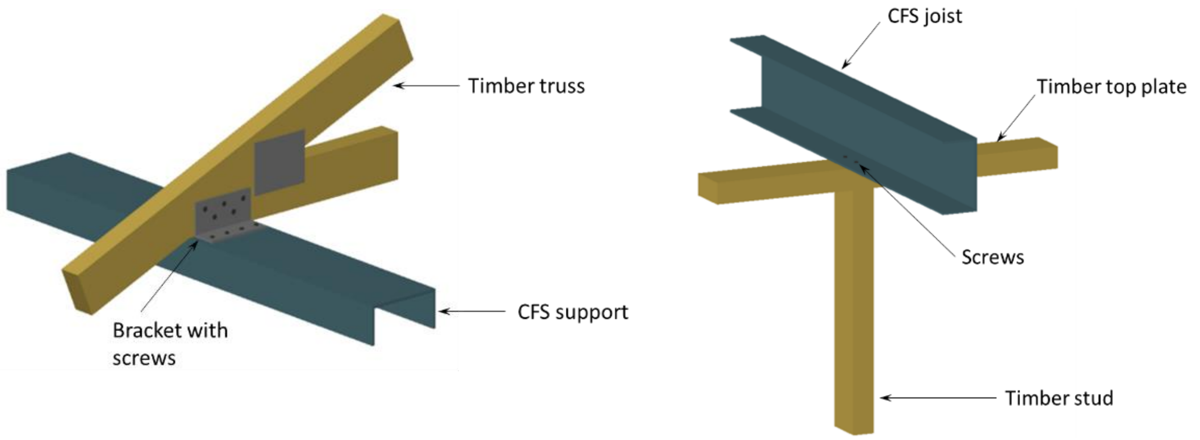
There are two types of timber-to-CFS connections:

(i) A fastener penetrates through either timber or CFS layer, e.g., when brackets are used to connect a timber member to a CFS member; or

(ii) A fastener penetrates through timber and CFS layers, e.g., when a screw is used to connect a timber member to a CFS member. For this type of connection, the fastener needs to be suitable to penetrate through timber and steel. Common types of connections which fall within this connection type are fasteners used to connect timber panels to CFS members for roof/floor diaphragms or shear walls.

Figure 1 shows examples of the two types of timber-to-CFS connections.

The guidance provided in this Technical Note is primarily suitable for timber-to-CFS connections where brackets are used to connect a timber member to a CFS member, and hence the fastener penetrates through either timber or CFS layer.



(a) Fastener penetrates through either timber or CFS layer

(b) Fastener penetrates through timber and CFS layers

Figure 1: Types of timber-to-CFS connections

2. Timber-to-timber connections

AS 1649 (Standards Australia, 2001) is the Australian Standard which provides the testing and evaluation method for timber-to-timber connections. It divides connection types into four categories:

- **Category A:** fasteners such as nails, staples and screws, which are used to connect timber members and the fastener may be subjected to either lateral or axial load.
- **Category B:** fasteners other than nails, staples or screws, acting as dowels, or the like, capable of transferring load from the face of one joint member to the other, where the two faces are lying in planes parallel to one another.
- **Category C:** fasteners acting as gussets or splice plates capable of transferring load from the face of one member to the face of another, where the two faces are lying in the same plane.
- **Category D:** fasteners acting as brackets capable of transferring load from the face of one member to the face of another, where the two faces involved are usually lying planes at right angles to each other.

AS 1649 provides a separate evaluation method for each of the four categories to calculate the characteristic capacity from design data. All of the methods initially involve calculating the basic working load (suitable for working stress design) and a factor is provided to convert to characteristic capacity (suitable for limit state design).

In general, the sampling and testing procedures in AS 1649 are considered to be suitable for timber-to-timber connections, however, the evaluation procedure is considered to be somewhat out of date as it involves numerous factors for which the origins are not completely well understood for calculating the basic working load and characteristic values. Hence, there is no clear definition for the calculated characteristic value.

In 2022, the Australian Engineered Fasteners and Anchors Council (AEFAC) developed a *Guide for the testing and evaluation of timber connection Category D,* referred to as the AEFAC Guide in this Technical Note. The aim of the Guide was to develop a different approach using prototype testing methodology for the derivation of the characteristic values, where the characteristic value is defined as the 5-percentile value with 75% confidence based on a lognormal distribution. In order to calculate the characteristic value, it is necessary to estimate the coefficient of variation of the reference population (with reference to a failure mode). If sufficient test data is available, the coefficient of variation can be approximated, if not, the suggested value in the AEFAC Guide may be adopted, where the coefficient of variation must be the larger of 20% or the value obtained from test data. The methodology is only applicable for the coefficient of variation up to 40%.

The AEFAC Guide also provides appropriate capacity factors for use in design together with and/or in place of other information provided in AS 1720.1 (Standard Australia, 2010), the Australian Standard for the design of timber structures. The AEFAC Guide also provides further detail and guidance on the sampling procedure, testing procedure, evaluation procedure, and test report requirements.

3. CFS-to-CFS connections

AS/NZS 4600 (Standards Australia, 2018) is the Australian and New Zealand standards for cold-formed steel structures. Section 5 of the standard provides provisions for determining the capacity of CFS-to-CFS connections, including welded, bolted, screwed, power-actuated fasteners, and blind-riveted connections. Section 8 of AS/NZS 4600 provides guidance for undertaking testing and evaluation of cold-formed steel members and connections.

The method in Section 8 of AS/NZS 4600 for testing for assessment or verification for full-size units of complete structures, parts of structures, or individual members and connections is similar to and based on the prototype testing methodology described in the National Association of Steel-framing Housing (NASH) Standard, *Residential and low-rise steel framing, Part 1: Design criteria*, referred to as the NASH Standard in this Technical Note. The evaluation method involves calculating the design value by using either the minimum or average value of the test results divided by a suitable sampling factor which is provided for different number of test results (sample size) and coefficient of variations. The design value is representative of the 5-percentile value with 99% confidence based on the Weibull distribution (see Wang and Pham, 2012). In order to determine the design value, it is necessary to estimate the coefficient of variation of the total population of the production unit. If comprehensive test data is available, it can be calculated, if not, the minimum values suggested in the NASH Standard or AS/NZS 4600 can be adopted, where a minimum coefficient of variation of 20% is suggested for obtaining the connection strength. The methodology is only applicable for the coefficient of variation up to 30%.

It is noted that the evaluation procedure in NASH Standard and AS/NZS 4600 obtains the design value directly from test data since a capacity factor of one is assumed (ϕ=1.0).

4. Timber-to-CFS connections

This section provides recommendations for timber-to-CFS connections, where brackets are used to connect a timber member to a CFS member. Hence for this type of connection, the fastener (e.g., screw or nail) penetrates through either timber or CFS member.

4.1. Sampling procedure

The sampling procedure is necessary to ensure that test specimens are representative of the reference population so that the test results can be used to determine design values for the reference population.

A sampling procedure has not been explicitly defined in AS 4600 or NASH standards for cold-formed steel connections. Detailed sampling procedure for Category D timber connections is provided in the AEFAC Guide and a general sampling procedure for timber is provided in AS 1649.

For timber-to-CFS connections, the sampling procedure defined in the AEFAC Guide and/or AS 1649 is suggested. In particular, it is important that the sampling procedure for timber is followed, and the timber selected for test specimens is representative of the intended joint group for which the design data is developed from tests.

In terms of sample size, the AEFAC Guide, AS 1649, AS/NZS 4600 and NASH standards for connections, require a minimum of 10 test values for a test series. As stated in the AEFAC Guide, the same failure mode should be observed for all specimens in a test series.

4.2. Testing procedure

The detailed testing procedure for timber connections is provided in AS 1649 and the AEFAC Guide, while no guidance is provided for CFS connections in AS/NZS 4600 and NASH standards.

4.2.1. Test specimens and test setup

AS 1649 provides details of various test specimen and setup configurations for solid timber. In general, these configurations are considered to also be suitable for CFS members.

Hence, for timber-to-CFS connections, it is suggested to adopt the configurations in AS 1649 with modifications made as necessary for the connection type under consideration.

As explained in the AEFAC Guide, exploratory testing is recommended to provide insights into the performance of the connection for the design of the test program. These include identifying relevant test factors considered appropriate for the proposed application, including relevant failure modes, sampling, testing conditions, edge and end distances, load angle to the grain of the timber, and minimum thickness of the timber.

The test setup, including the specimen configurations, supports for the specimen, and application of the load, shall be determined in such a way that the actions on the test specimen simulate the actions of the actual service conditions of the joint.

4.2.2. Application of load

Both AS 1649 and the AEFAC Guide provide guidance for the application of static monotonic load. For some cases, the rate of crosshead moment (0.06 mm +/- 25% per minute) suggested in AS 1649 for Category D fasteners may not be suitable. The AEFAC guide provides more general guidance, suggesting that the maximum load should be reached in approximately 5 to 10 minutes. Further guidance is provided in the AEFAC Guide, and this is suggested to be suitable for timber-to-CFS connections.

4.2.3. Instrumentation and load-deformation curve

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

The deformation of the connection should be continuously measured using a suitable displacement measurement device (e.g., LVDTs). It is preferable to have two displacement measurement devices to measure the displacement such that the slip of the connection can be taken as the average of the displacement measured by the two devices.

4.3. Evaluation procedure

The evaluation procedures in AS 1649 and the AEFAC Guide are different, and these procedures are both different to those in AS/NZS 4600 and NASH Standard. In general, it is suggested that the evaluation procedure selected should correspond to the failure mode and the suitable standard.

4.3.1. Characteristic capacity

The characteristic value from test data should be calculated based on selecting the suitable standard or guide corresponding to the observed failure mode:

- **For failure in timber:** either the evaluation in the AEFAC Guide or AS 1649, should be used. In general, the evaluation method in the AEFAC Guide is preferred to the method in AS 1649, since it directly calculates the characteristic value from test values without needing to calculate the basic working load and selecting suitable factors to convert to characteristic capacity.

- **For failure in CFS:** the evaluation procedure in AS/NZS 4600 or NASH Standard should be adopted. The evaluation procedure in AS/NZS 4600 and NASH Standard are similar, where they both suggest two methods for calculating the design value; one method uses the minimum value obtained from the tests and the other uses the mean value of test results. It is suggested to use the method that uses the mean of the test values to calculate the design value as it usually ensures more consistent and reliable results. It is noted that AS/NZS 4600 and NASH Standard directly calculate the design capacity from test data, where it is assumed that the capacity factor is one (i.e., ϕ=1.0).
- **For combined failure in timber and CFS:** the more conservative evaluation procedure for timber or CFS connection should be adopted which is, in general, the AEFAC Guide (if it is selected instead of AS 1649 for failure in timber).

4.3.2. Capacity factor

The capacity factor selected to obtain the design value from characteristic value should correspond to the standard or guide adopted for the evaluation procedures:

- **For failure in timber:** if the characteristic value has been calculated using the AEFAC Guide then the capacity factors suggested in the AEFAC Guide shall also be selected (i.e., ϕ=0.70, 0.65, or 0.60 for Category 1, 2, and 3 application of the structural member, respectively, as defined in AS 1720.1:2010). If the characteristic value has been calculated using AS 1649, then the capacity factors in AS 1720.1:2010 may be applicable.
- **For failure in CFS:** where the design capacity of the connection is determined from test data in accordance with AS/NZS 4600 or NASH Standard, the assumed value for the capacity factor is one (i.e., ϕ=1.0).
- **For combined failure in timber and CFS:** the more conservative evaluation procedure for timber or CFS connection should be adopted, and the corresponding capacity factors in the standard or guide.

4.3.3. Reporting requirements

Technical data sheets which provide characteristic capacities of timber-to-CFS connections should specify:

- The evaluation method, that is, the standard or guide that has been used to obtain the characteristic value from test data, and
- The failure mode for the given conditions (e.g., timber joint group, CFS member thickness) for which the characteristic capacity is applicable. In particular, care should be taken when the failure mode changes for different timber joint groups.

The evaluation method and failure mode should be specified as it determines the selection of the suitable capacity factor for design.

4.3.4. Extrapolation of test results

For CFS, AS/NZS 4600 and NASH Standard state that for prototype testing, no extrapolation of test values is permitted. Only interpolation is allowed if prototype testing is conducted for a range of specific parameters (e.g., thickness of CFS sections) to determine design values for a specific product, provided that the is no change in the structural behaviour within the interpolating range.

For timber, the rules around extrapolation of test results are less clear, in particular in relation to extrapolating results for different timber joint groups.

The AEFAC Guide aimed to provide more clarity in relation to assigning test results to suitable a joint group based on the actual density of the timber used for the specimens. This was achieved by providing a method for correcting for timber density for a limited range of timber density above and below the mean timber density of the tested specimens, provided that, it was demonstrated that the failure in timber, rather than failure in the metal, would take place. In addition, it is assumed that perpendicular to the grain tension failure does not govern the failure mode.

For timber-to-CFS connections, it is suggested that no extrapolation of test results is allowed as explained in AS/NZS 4600 and NASH Standard, except to allow for correction for timber density if it is demonstrated that failure in the timber will take place, rather than: (i) failure in the metal bracket or fastener, or (ii) failure in the CFS.

References

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