EUROPEAN ASSESSMENT DOCUMENT

EAD 130186-00-0603

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THREE-DIMENSIONAL NAILING PLATES

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 Scope of the EAD

1.1 Description of the construction product

This EAD covers an assessment of preformed three-dimensional metal nailing plates made of steel or aluminium with specified fasteners.

The specified fasteners include for example nails, screws, bolts, pins and dowels.

This EAD is intended to cover all types of three-dimensional nailing plates, a non-exhaustive list of examples of which are given in Figure 1 and possible configurations are given in Figure 2.

The EAD does not cover:

- Products covered by Mandate M112 to CEN for 'Structural timber products and ancillaries
- Joist hangers covered by Mandate M116 to CEN for 'Masonry and related products' (as 'ancillary components'),
- Use of three-dimensional nailing plates in pile foundations.

The EAD cover the assessment of a product consisting of the three-dimensional nailing plate and specified fasteners. Both the three-dimensional nailing plates and the fasteners are specified in the ETA. It is possible that the fasteners included in the kit are not produced by the ETA holder. If the fasteners are already CE marked, it is not necessary to test the fasteners themselves again in connection with this EAD.

The products are not covered by a harmonized standard (hEN).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

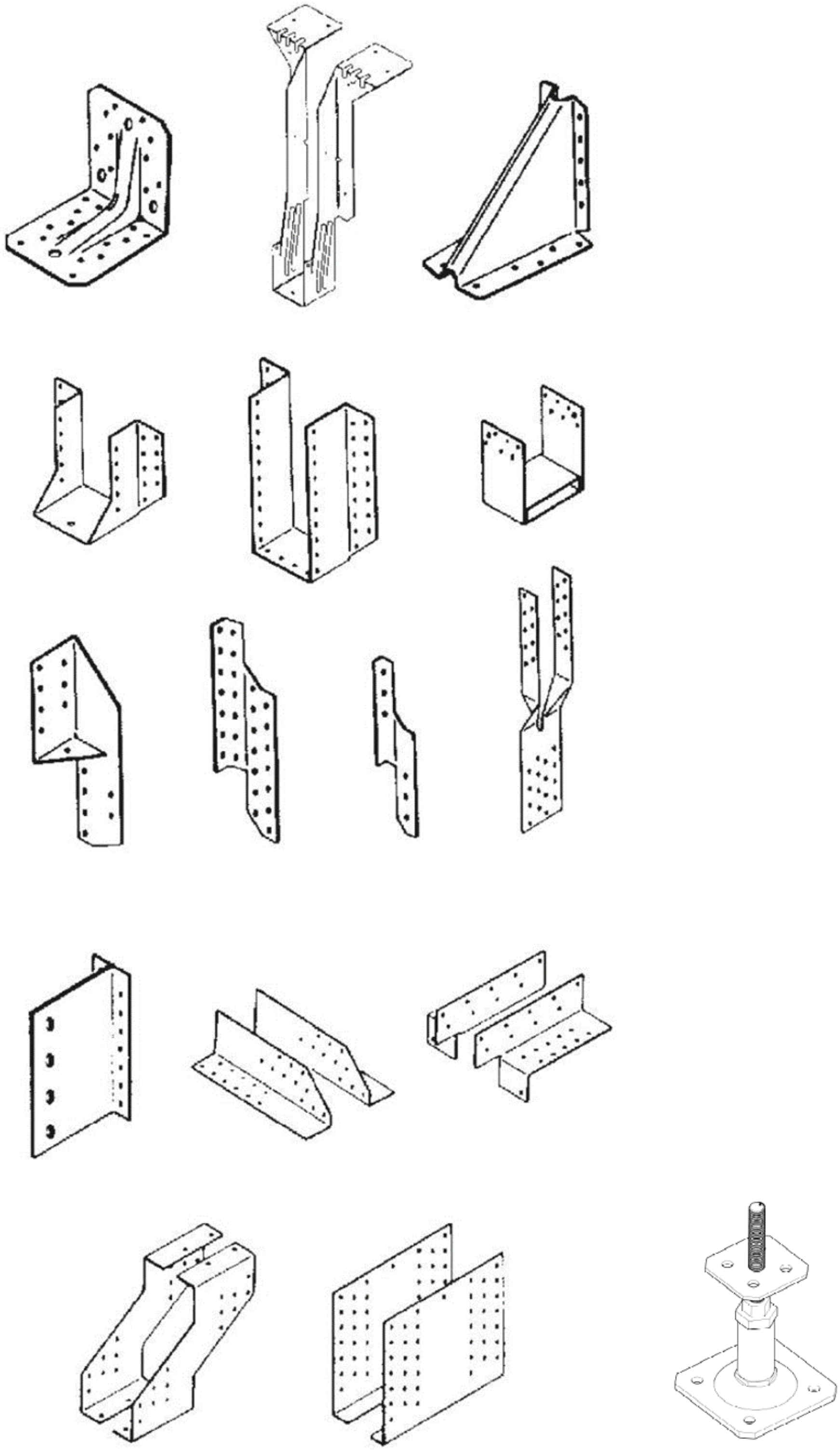
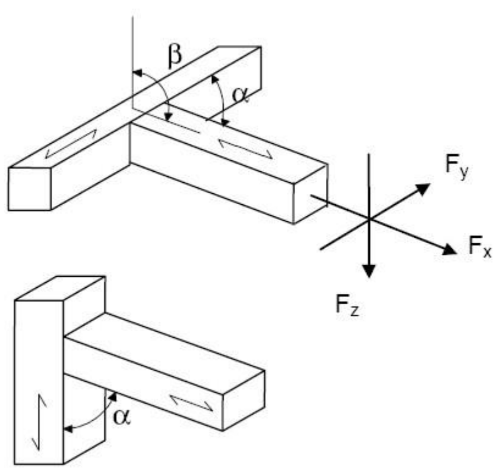
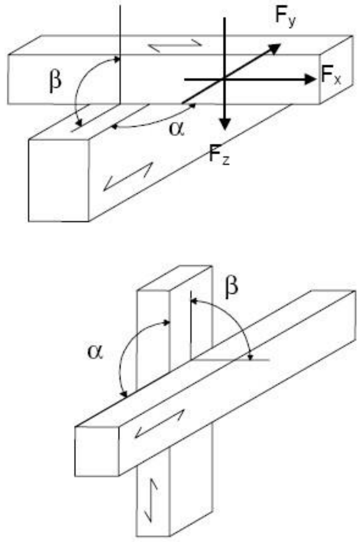


Figure 1 – Examples of three-dimensional nailing plates





Arrangement and loading of timber members with end-grain to side-grain

Arrangement and loading of timber members with side-grain to side-grain

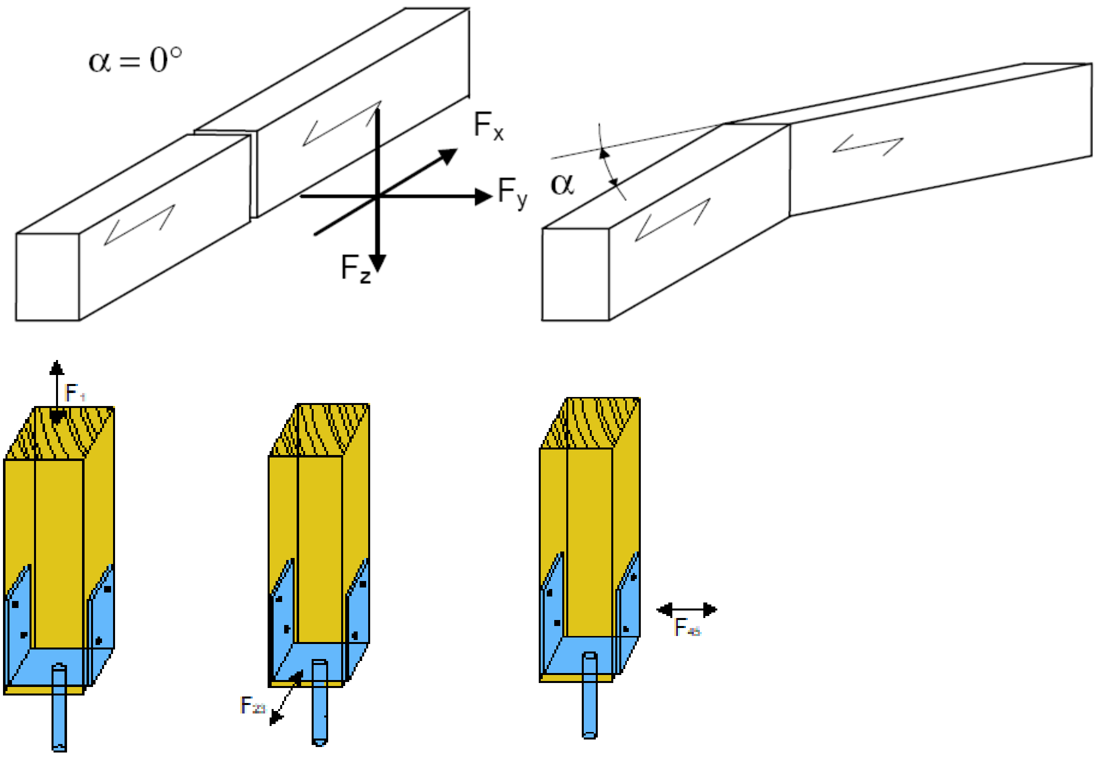


Figure 2 – Examples of configurations of timber members

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

This EAD covers the assessment of three-dimensional metal nailing plates with specified fasteners for use as connections in loadbearing timber structures and their supports, for which a load-carrying capacity and, where appropriate, a stiffness will be assessed.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the three dimensional nailing plate for the intended use of 50 years when installed in the works. These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[1].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Terminology

Unless otherwise stated, the terminology used in EN 1995-1-1 applies.

The modified characteristic load-carrying capacity $X_{k,mod}$ is the 5% fractile in the distribution of the load-carrying capacity for the stated relevant load duration and service class. It is equal to $k_{mod}X_k$ as given in EN 1995-1-1.

Wane	original rounded sapwood surface of a log, without bark, on any face or edge of sawn timber.
Square-edged timber	sawn timber of rectangular cross-section, with wane, if permitted, not exceeding a specified amount.
Connection	Joint. EN 1995-1-1 make reference to 'joints', accordingly, this EAD uses 'joints' rather than the equivalent term 'connections'

1 The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than the assumed working life.

2 Essential characteristics and relevant assessment methods and criteria

2.1 Essential characteristics of the product

Table 1 shows how the performances of the three dimensional nailing plates are assessed in relation to the essential characteristics.

Note. All undated references to standards or to EAD's in this chapter are to be understood as references to the dated versions listed in clause 4

Table 1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance *(level, class, description)*
Basic Works Requirement 1: Mechanical resistance and stability			
1	Joint strength	2.2.1	Level
2	Joint stiffness		
3	Joint ductility		
4	Resistance to seismic actions	2.2.2	Level
5	Resistance to corrosion and deterioration	2.2.3	Description
Basic Works Requirement 2: Safety in case of fire			
6	Reaction to fire	2.2.4	Class
7	Resistance to fire	2.2.5	Class

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 Joint strength, joint stiffness and joint ductility

Three-dimensional nailing plate joints are assessed to resist forces with specified positions and/or moments in several directions. At least one force direction shall be assessed and stated in the ETA.

The mechanical resistance and stability of three-dimensional nailing plates can be verified using:

- calculation,
- calculation assisted by testing,
- testing.

The force and moment capacity shall be determined for deformations of the timber members similar to those of the structures in which they are intended for use.

The manufacturer specifies either the strength class according to EN 338 or the species, grade and surface finish of the timber or structural timber composite. As default the capacities determined for the tested timber (see section 2.2.1.3) are stated in the ETA. If the capacities are extended to other timber types, the conditions for this is stated in the ETA.

The possible existence of wane shall be considered. If wane is allowed, the maximum extent of wane allowed in the specification shall be used in the calculations or testing.

The support and restraint conditions are specified by the manufacturer. If this information is not specified, the assessment of the product is not covered by the scope of this EAD

The support and restraint conditions for the members are critical to the performance and hence the characteristic loads of the three-dimensional nailing plate, and shall reflect the stated intended use.

The manufacturer may specify possible preparation of timber members, e.g. pre-drilled holes, tolerance on hole diameter, which is taken into account by the TAB in the assessment procedure.

The mechanical resistance and stability is determined taking into consideration the gaps between the timber members that can occur in practice. For side-grain to side-grain connections it can be assumed that the timber members are brought close together without any gap. For end-grain to end-grain and for end-grain to side-grain connections the maximum permitted size of the gap is considered and, in no case, shall be smaller than 3 mm between mating faces (timber-timber or timber-three-dimensional nailing plate). To avoid the possibility of failure by a zipper effect, failure of the fasteners shall not take place by head tear-off.

2.2.1.1 Calculation

2.2.1.1.1 General

Calculations can be used as the means of assessment if the three-dimensional nail plate is of a ductile material and if either of the following conditions is fulfilled:

- the static behaviour of the joint is ductile and if the components of the joint have a ductile force-deformation behaviour,
- if the static behaviour of the mechanical fasteners (nails or screws) is governed by pull-out of the fastener, then the force distribution over these shall be determined statically or based on a conservative assumption, i.e. calculation according to EN 1995 section 8. Differences is axial deformations shall not be neglected
- Failure of the fastener in tension, e.g. (head tear-off or tear-off in the area of thread) is not allowed to be used as the assessed performance of the connection

Three-dimensional nailing plates of steel in accordance with EN 10111, EN 10088-2 or EN 10346, with a 0,2 % proof strength ≤ 350 $N \cdot mm^{-2}$ are considered as ductile in the framework of this EAD.

The calculations are carried out in accordance with EN 1995-1-1 section 8 and depending on the material of the nailing plate, EN 1993 or EN 1999. Examples of methods which may be used for calculations are given in Annex A Principles for the static calculation of connections made with three-dimensional nailing plates, with examples.

The calculations are based on the characteristic material properties for the appropriate load duration and service class, calculated in accordance with EN 1995-1-1 using the factor k_{mod}.

Where relevant, the deformations of the connection shall be calculated as described in EN 1995-1-1 and in accordance with load levels given in EN 26891.

The values of the instantaneous slip modulus K_{ser} given in EN 1995-1-1 are used in the calculations.

2.2.1.1.2 Properties of materials and components

The properties of the materials and the components of the three-dimensional nailing plate joints are specified by the manufacturer by reference to the relevant European Standards depending on the material of the nailing plate, and stated in the ETA.

For the steel or aluminium parts, the specified yield stresses and the ultimate stresses are stated in the ETA.

For the nails, screws, dowels, bolts, pins or other fasteners subjected to lateral load or to axial load the load-carrying capacities and the stiffness is calculated as described in EN 1995-1-1 section 8 based on the information in the Declaration of Performance of the fastener including the relevant timber characteristics.

2.2.1.1.3 Static models

The calculation of the nailing plate joints shall take into account the internal forces and the deformations of the timber members, which come from the global analysis of the structure. The deformation of the connected timber members and the components in the three- dimensional nailing plate connection shall be assumed compatible with those from the global analysis of the structure.

The analysis of a three-dimensional nailing plate joint shall take into account the static behaviour of all parts, which constitute the joint.

Equilibrium shall be fulfilled in any part of the joint. If used, the finite element analysis shall comprise the three-dimensional nailing plate, the fasteners, the connected members and the supports, if any. All eccentricities shall be considered.

It shall be documented that the internal forces in the three-dimensional nailing plate joints are less than or equal to the capacities.

The limited deformation capacity of the components in the three-dimensional nailing plate joints shall be considered.

For threaded nails and screws subjected to a lateral force and having a penetration depth $l > 9d$, where d is the diameter of the nail or screw as defined in EN 1995-1-1; is considered to be an elastic-plastic behaviour in the context of this EAD.

The calculated loadbearing capacities in the corresponding load directions, nailing patterns shall be stated in the ETA.

2.2.1.2 Validation of static model by testing

2.2.1.2.1 General

The principles described in section 2.2.1.1 apply. Calculation assisted by testing comprises:

- validation of the static model,

- determination of properties of the component by test or declared by the component manufacturer and documented values as input data for the static model, e.g. the yielding moment of an embossed nailing plate section

2.2.1.2.2 Scope of testing and calculations

The scope of the testing is to verify or calibrate a theoretical static model of the three- dimensional nailing plate connections and to derive properties where calculation is not practical or possible for particular properties.

The model shall reflect and validate the actual static behaviour.

Note. The validation of the static model can be subject to boundary conditions, which shall be taken into account in the assessment

A static model for the ultimate load-carrying capacity of the joint can only be assumed to be verified, if the model for the load-carrying capacities of the connection components can predict the load-carrying capacity of the connection.

The static model shall be validated for the type of forces in the joint and for the range of their position.

The model shall be validated for the range of eccentricities to be used in the calculations.

The validation shall give special consideration to the case of axial loaded nails or screws. From the validation tests, it shall be possible to establish either the effective number of nails or screws or the effectiveness of the nails or screws.

For three-dimensional nailing plates with special cross-sections or varying cross-sections, e.g. pressed or deformed cross-sections, the bending capacity of the three-dimensional nailing plate cross-sections can be determined by testing (see section 2.2.1.3).

For three-dimensional nailing plates incorporating screws parallel to grain into end–grain, the following shall be considered:

- the effects of splitting due to variations in moisture content,
- the number of fasteners,
- length and diameter of fasteners,
- the need to validate the model by tests of the whole joint.

Testing is performed in accordance with section 2.2.1.3 to validate the load carrying capacity of the joint.

2.2.1.2.3 Testing of properties

The requirements of section 2.2.1.3 apply.

The moisture content and density of the timber are determined in accordance with EN 13183-2 and EN 384 respectively.

The relevant properties related to the metal components are determined in accordance with EN 10111, EN 10088-2, EN 10346 and EN 755-2 respectively.

Testing of the bending capacity of three-dimensional nailing plates with profiled cross-sections are carried out in a way that the bending of the three-dimensional nailing plate corresponds to the actual moment distribution of the three-dimensional nailing plate in the connection.

The vertical flange of three-dimensional nailing plate is clamped by bolts in the nail holes, and subjected to the force causing bending by a tension rod through a hole in the three-dimensional nailing plate, as shown in Figure 3.

By applying the force in the downward or upward direction, a bending moment can be applied to the three-dimensional nailing plate with tension or compression stresses in the deformed part of the cross-section as would occur in the actual connection.

The bending moment is determined by applying a force at a chosen eccentricity – the eccentricity, e, is the distance from the vertical part of the angle bracket to the position of the applied force. The bending moment is calculated from the eccentricity multiplied by the force at break. The force is applied in the centreline of the angle bracket, i.e. in the same line as the rib.

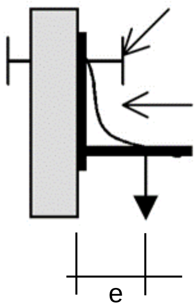


Figure 3 – Example of test assembly

2.2.1.3 Testing

2.2.1.3.1 General

Testing for joint strength and stiffness are carried out in accordance with EN 26891.

Due to the large variation in products covered in this EAD, it is not possible to set rules for each product. The general principles, which are adopted for the tests, are given below. Examples are given in Annex B

1. Determine cross-sections of primary and secondary members according to intended purpose and function and use these members in full scale during the tests.
2. Choose the test configuration to avoid failure due to effects outside the scope, e.g. failure due to tension perpendicular to the grain in the timber, bending failure of the secondary member, bearing failure at the loading points shall not be present.
3. Choose the test configuration of the secondary member such that the deformation of the connection in the test zone reflects the intended use.
4. Avoid undue influence arising from the method of load application and member support which defines the intended purpose and function, e.g. loading shall only be applied in the connected area if this covers the intended use.
5. Make sure that the load transmission principles within the arrangement are determinable, e.g. by using additional load cells to determine the exact load transferred by the connection; if relevant, the mass of the test equipment shall be taken into account in the recorded data.
6. Measure the relative displacements between the members and take into consideration that undesirable influences are avoided by fixing the transducers at points away from the expected failure zone; place the transducers on either side of the specimen and average the results to take into account any distortion of the members.
7. Take into account that practical tolerances in the fit between the connected members can influence the load-carrying capacity of the connection, e.g. by arranging appropriate gaps between the members.
8. Assemble the test pieces with the timber at an equilibrium moisture content corresponding to 20 ± 2 °C and 85 ± 5 % relative humidity, condition the assembly to 20 ± 2 °C and 65 ± 5 % relative humidity until just before testing, and measure the moisture content at the time of testing. For engineered wood products conditioning at 20 ± 2 °C and 85 ± 5 % relative humidity before assembly is not necessary. Other conditioning regimes shall be considered on a case-by-case basis and be reported in the ETA.
9. Determine and record the relevant specifications of the materials, e.g. the quality or grade of the timber, the specifications and dimensions of the metalwork and other fasteners, and mention in the test report that the test results do not necessarily apply to other types of metalwork or timber.
10. A record of load-deformation behaviour shall be made with a minimum frequency of 10 Hz for each test arrangement.

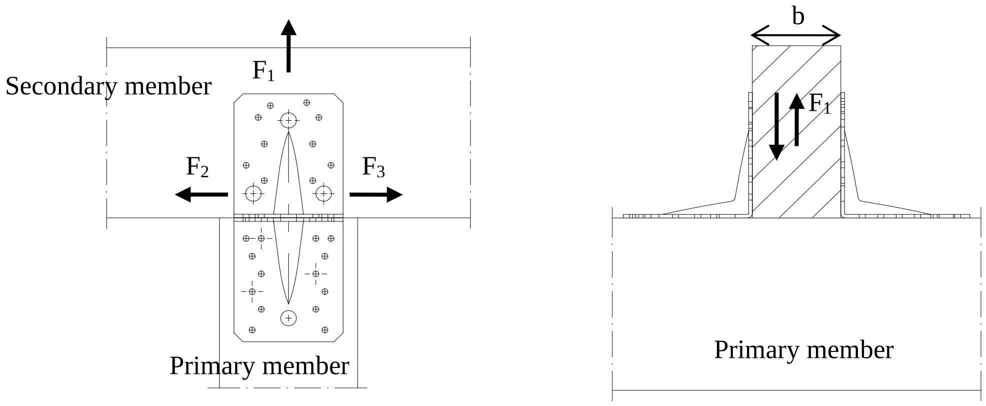


Figure 4. Illustration of example of primary and secondary member

2.2.1.3.2 Materials and properties

The extent of testing depends on the type of documentation of load-bearing capacities:

- For calculations, the load-bearing capacities of the ancillary components are needed.
- For calculation assisted by testing, the capacities of the components of the joint are needed to verify the static model.
- For modification of the test results of the particular joint capacities, the load-carrying capacities of the ancillary components and the strength properties of the three-dimensional nailing plate are needed.

Timber and wood-based materials

The timber is selected in accordance with the method given in EN ISO 8970. The densities for species are taken from EN 338.

Unless otherwise specified by the manufacturer, the tests are carried out using European Whitewood (Picea abies).

Wood-based materials, e.g. engineered timber products such as parallam or intrallam are selected in a similar manner to that for timber.

For a group of similar test pieces, separate planks are used for each test piece.

The timber used for the samples for testing shall not crack during preparation of the samples. This can be prevented by:

- a minimum of six screws into end grain are used when the holes are not pre-drilled or minimum three screws when the holes are predrilled,
- the minimum length of fastener is 50 mm,
- the minimum diameter of fastener is 4 mm and maximum 8 mm, however maximum 10 mm when the holes are pre-drilled,
- the moisture content of the timber in test sample is below 18 %.

The members shall be free from major defects in the area of the three-dimensional nailing plates. However, where wane is allowed, the test shall be conducted with the maximum extent of wane (artificially produced by cutting if necessary) allowed by the specification, as described in the beginning of this section.

2.2.1.3.3 Three-dimensional nailing plates

The relevant characteristic properties (e.g. ultimate tensile strength, yield stress and elongation) of the metal used to manufacture the three-dimensional nailing plates, taken from the coil or strip used in manufacture, are determined using standard test procedures (e.g. EN ISO 6892-1).

Most three-dimensional nailing plates are produced in a range of sizes; the sizes of three- dimensional nailing plates to be used in the various tests are selected in such a way that the strength and stiffness of the complete range may be obtained by interpolation provided the failure mechanism is the same.

2.2.1.3.4 Associated ancillary components

The below assessment methods applies only for the nails, screws, dowels, bolts, pins or other fasteners when the assessment covers a product consisting of the three-dimensional nailing plate and the fasteners.

For the nails, screws, dowels, bolts, pins or other fasteners subjected to lateral load or to axial load the load-carrying capacities and the stiffness is calculated as described in EN 1995-1-1 section 8 based on the information in the Declaration of Performance of the fastener including the relevant timber characteristics

For nails or the screws subjected to lateral load or to axial load, but not covered by a Declaration of Performance, the load-carrying capacities and the stiffness is calculated as described in EN 1995-1-1 section 8 based on the tests described in EN 1380, EN 1382, EN 1383 and EN 26891. The tests shall be conducted with relevant timber species with density according to EN ISO 8970.

The ancillary components used in the tests shall be representative and shall be drawn at random.

The tensile capacity of the nail or screw (head tear-off or tear-off in the area of thread) are determined in accordance section 6.2.4.4 or 6.3.4.5 respectively of EN 14592:2008+A1:2012.

2.2.1.4 Test methods for joints

2.2.1.4.1 General

Generally, three-dimensional nailing plates are available in a range of sizes; some can also be used with a range of timber sizes and a range of fasteners/fastener sizes. In producing a test specification, consideration is given to the three-dimensional nailing plate sizes, the fasteners and timber member combinations. For specified fasteners, testing the largest and smallest three-dimensional nailing plates and only one or more of the intermediate sizes can be applied. Interpolation for intermediate sizes may be used to determine three- dimensional nailing plate load capacity, where other physical properties remain the same (e.g. material specifications, materials irregularities and material section properties). To confirm the assumed interpolation formula, tests may be necessary. To achieve test results that reflect the load capacity of the three-dimensional nailing plate and not the timber strength, selecting the largest timber size for a range of three-dimensional nailing plate sizes may be appropriate.

The minimum number of specimens to determine the following values is:

- mean value: three specimens,
- characteristic value: five specimens.

However, it is permissible to disregard a test result where the failure has taken place outside the connection.

The support and restraint conditions are those specified by the manufacturer.

2.2.1.4.2 Conditioning

See 2.2.1.3.1 bullet 8. For engineered wood products conditioning at 20 ± 2 °C and 85 ± 5 % relative humidity before assembly is not necessary. Other conditioning regimes are considered on a case-by-case basis and be reported in the ETA. The timber material is conditioned when it attains constant mass. The conditioning time depends on the sizes of the timber members. For timber members of a thickness of up to 65 mm a constant mass is considered to be attained when the results of two successive weighings, carried out at an interval of six hours, do not differ by more than 0,1 % of the mass of the timber material. For larger thickness it may be necessary to use longer time between the readings than 6 hours but the same 0,1 % applies. For other products other moisture conditioning may be appropriate, and shall be reported. For some hardwoods, a much longer conditioning period may be necessary.

2.2.1.4.3 Assembly of test pieces

The size and geometry of the test pieces will depend upon the type of three-dimensional nailing plates and the property being measured, and are representative of the connection under practical conditions. The test pieces are assembled using the method(s) specified by the manufacturer with the particular three-dimensional nailing plates.

Timber members for test pieces are cut so that the areas to which the three-dimensional nailing plates are fixed are free from knots, local grain disturbance, fissures and wane (except to the extent described in the beginning of this section). Elsewhere, the members are free from characteristics which could lead to premature failure in the timber.

The fabrication of the test pieces shall reflect the gaps which can occur in practice.

2.2.1.4.4 Test procedure

2.2.1.4.4.1 Estimation of maximum load
The estimated maximum load $F_{max,est}$ for the type of joint to be tested shall be determined on the basis of experience, or by calculation, or from preliminary tests, and shall be adjusted as required by the loading procedure.

2.2.1.4.4.2 Loading procedure
The loading procedure given in section 8 of EN 26891 is followed.

2.2.1.4.4.3 Maximum load
The load reached before or at a slip of 15 mm is recorded as the maximum load for each specimen. The slip is measured as the relative movement between the centres of gravity of the timber members of the connection in the direction of the applied load, see section on Deformation.

The testing continues until the maximum load (F_{max}) is achieved or 15 mm slip is reached. For the purposes of determination of adjustment factors (see annex B) based on failure mode, if failure is not considered to have occurred at 15 mm slip, testing continues until an alternative failure mode can be determined. The maximum load (F_{max}) or load at 15 mm slip (F_{15}) shall be reported together with the failure mode.

$F_{max,mod}$ is taken as F_{max} within maximum 15 mm slip modified by a factor based on the failure mode.

Technical Report 016 gives under certain conditions guidance for how the modification shall be performed when failure does not take place within 15 mm slip without continuing the testing until failure.

The compression capacity shall be taken as the highest load required to close the gap between the timber members.

Note: This will define the load-carrying capacity of the actual three-dimensional nailing plate connection, but not necessarily of the connection as a whole.

2.2.1.4.4.4 Deformation
Deformations is taken as the relative movement between the centres of gravity of the timber members being joined in the direction of the applied load (δ_m) in mm.

2.2.1.4.4.5 Test report
The test report includes:

- the timber species and grade, and the surface finish, density and moisture content of the timber,
- method for selecting timber density, by reference to EN ISO 8970,
- dimensions of the joints, size of the three-dimensional nailing plates, details of gaps between the members,
- specification of any fasteners used, e.g. nails, screws, by reference to an appropriate standard or other relevant specification,
- conditioning of the timber and test pieces before and after fabrication,
- the loading procedure used, and a statement of any deviations from these procedures,
- product specification, including the dimensions, coating thickness, if appropriate, and specified mechanical properties (e.g. tensile strength, yield stress and elongation) of the metal used to manufacture the product,
- method of installation,
- individual test results of maximum load and any relevant information regarding adjustments, descriptions of the modes of failures, density of timber in which failure took place,
- initial slip and slip modulus according to EN 26891, and load–slip curve.
- low-cycle fatigue joint behaviour in accordance with EN 12512, where appropriate for seismic performance.

2.2.1.5 Determination of strength, stiffness and ductility

Where properties are claimed for more than one direction of loading, each shall be given together with the below interaction equation corresponding to the force directions (example of all force directions). Consideration is given to the duration of load, the effects of reversal of load from long- and medium-term actions and alternating between tension and compression actions in the members.

$$\left(\frac{F_{1,d}}{F_{Rd,1}}\right)^2 + \left(\frac{F_{2,d}}{F_{Rd,2}}\right)^2 + \left(\frac{F_{3,d}}{F_{Rd,3}}\right)^2 + \left(\frac{F_{4,d}}{F_{Rd,4}}\right)^2 + \left(\frac{F_{5,d}}{F_{Rd,5}}\right)^2 \leq 1$$

2.2.1.5.1 Strength

The characteristic load-carrying capacity X_k or the modified load-carrying capacity $X_{k,mod}$ (X corresponds to relevant designator in EN 1995-1-1 section 8) for a given load duration, and service class defined in EN 1995-1-1 section 8 and 2.3.1.3 respectively is stated in the ETA.

For assessment by 'calculation' and 'calculation assisted by testing' this is derived in accordance with the requirements of EN 1995-1-1 and for assessment by testing in accordance with EN 14358.

When deriving values from tests, account is taken of the density and moisture content of the timber test specimens, and deviations from the minimum specification for material properties of the three-dimensional nailing plate and ancillary components (see Annex B).

2.2.1.5.2 Stiffness

Where an initial slip and slip modulus are to be stated in the ETA, they shall be determined as described in EN 26891. This relationship shall cover the serviceability limit state covering forces up to 40 % of the ultimate force F_{ult}.

For assessment by tests, these properties are determined in accordance with EN 26891, section 8.5:

- initial slip v_i,
- slip modulus k_s (K_{ser} in EN 1995-1-1).

The bolt hole diameter compared to the hole diameter is considered in the load-slip relation

2.2.2 Resistance to seismic actions

In seismic zones, a dissipative structural behaviour may be assumed if an appropriate low- cycle fatigue behaviour of the joints is verified by cyclic testing in accordance with EN 12512, as required by EN 1998-1:2004.

In seismic zones, dissipative structural behaviour may be adopted in design if joints are able to deform plastically for at least three fully reversed cycles in cyclic testing in accordance with EN 12512 at a static ductility ratio of 4 for ductility class M structures and at a static ductility ratio of 6 for ductility class H ones, without more than a 20 % reduction of their resistance, as laid down in section 8.3(3) of EN 1998-1.

When preparing the test specimen in accordance with EN 12512 both the connection between the timber and the nailing plate and the nailing plate and the substrate shall be included in the test specimen. The sample and the relevant substrate to be tested is the one presented to the TAB by the manufacturer.

Moreover, in order to ensure a stable behaviour under cyclic loading, if the intended use is in dissipative structures in seismic areas, the energy dissipated in the 3rd cycle shall be not less than the 80 % of the energy dissipated in the 1st cycle. If so, a seismic performance cannot be stated in the ETA.

The assessment of the energy dissipated in the cycle, evaluated as the equivalent damping of the hysteretic energy dissipation, is performed according to EN 15129 section 4.5.3.

If the above requirement is fulfilled this is stated in the ETA together with information about the capacity and ductility in accordance with EN 12512.

2.2.3 Resistance to corrosion and deterioration

The product (including associated ancillary components) are assessed to determine the thickness of corrosion protection or the material specification.

If a zinc coating is used its thickness is determined by:

- hot-dip galvanized coating to EN ISO 1461, using the methods described in the standard, using the non-destructive magnetic method of EN ISO 2178, or using the gravimetric method of EN ISO 1460 as a reference method in case of dispute,
- hot-dip zinc-coated sheet to EN 10346 using the non-destructive magnetic method of EN ISO 2178, or using the methods described in Annex A of the standard in the case of dispute,
- electroplated zinc coating to EN ISO 2081 table C1, using the methods described in the standard, or using EN ISO 2177 as a reference method in case of dispute.
- If stainless steel is used, it shall be designated in accordance with EN 10088-1.
- If aluminium is used, it shall be designated in accordance with an appropriate standard.

The materials' specification or minimum corrosion protection for different service classes are stated in accordance with EN 1995-1-1. Alternative materials may be used provided that they have sufficient corrosion protection for the proposed intended use shown by assessment or testing taking into account the connection points between the nailing plate and the fastener and that they do not change performance of the nailing plate. Alternative corrosion protection materials are assessed in accordance with the principles in FprEN 14592:2018-02 section 5.2 applied the both the fastener and nailing plate.

Note. The edges of hot-dip zinc coated-steel sheet to EN 10346, with a minimum coating mass of Z275, are galvanically protected by the zinc present on the faces of the sheet, and are known to have satisfactory long-term service in service class 2 provided the steel thickness is less than or equal to 3,0 mm.

It is noted that standards for galvanized and electroplated coatings express mass/unit area of coatings with respect to the surface area, and standards for hot-dip coated sheet express mass/unit area with respect to the area of the sheet (i.e. the area of a sheet represents half the area of its surface).

Any corrosion resulting from contact of materials with the three-dimensional nailing plate, including the different materials used in the construction of the joint including the fasteners, in the service classes being considered is stated in the ETA. Where appropriate, the product specification (including any ancillary components) is assessed to determine whether any risk of bimetallic corrosion exists (with reference to the electrochemical series), and any evidence of monitored atmospheric exposure tests to EN ISO 7441 is assessed.

Any corrosion resulting from contact of materials with the three-dimensional nailing plate, including the fasteners, the timber species and preservative treatments proposed for use in the service classes being considered shall be stated in the ETA. An assessment shall be made of the risks of corrosion arising from any proposed preservative treatment for the timbers used with the product, or with any acidic or corrosive timber species, e.g. hardwood, proposed for use.

The three-dimensional nailing plate and associated fasteners are assessed and any occurrence of corrosion or potentials for bimetallic corrosion is described in the ETA.

2.2.4 Reaction to fire

The three dimensional nailing plates are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the EC Decision 96/603/EC amended by EC Decision 2000/605/EC without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

The three dimensional nailing plate not covered by the above decision shall be tested, using the test method(s) relevant for the corresponding reaction to fire class, in order to be classified according to Delegated Regulation (EU) 2016/364 and EN 13501-1.

The classification shall be stated in the ETA.

When required by the manufacturer, the reaction to fire class according to Delegated Regulation (EU) 2016/364 and EN 13501-1 of components included can be stated in the description in the ETA.

2.2.5 Resistance to fire

The three dimensional nailing plate is tested, using the test method relevant for the corresponding fire resistance class, in order to be classified according to EN 13501-2.

The test configuration shall be determined based on the intended end use conditions for the complete structural element with any associated finishes.

The test is performed using specimens made from timber representative of the strength class with a density which is within ± 5 % of the mean density of the strength class for which the fire resistance shall be applicable.

Failure shall be considered to occur either when collapse of the connection occurs or when the slip at the connection (the relative movement) between the centres of gravity of the connected members in the direction of the applied force reaches 30 mm.

The classification and field of application are given in the ETA.

3 Assessment and verification of constancy of performance

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 97/638/EC of the European Commission

The applicable AVCP system is 2+ for all uses

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 2.

Table 2 Control plan for the manufacturer; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method *(refer to 2.2 or 3.4)*	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC)					
1	Checks on incoming materials	Control of specification	Specified in control plan	Every batch	Every delivery
2	Corrosion protection	Control of specification	Specified in control plan	Every batch	Every delivery
3	Checks on finished products: Dimensions Standard of welding (where appropriate)	Visual inspection Calliper and/or gauge	Specified in control plan	Specified in control plan	Specified in control plan
4	Fasteners	Control either: • by means of reference to HTS in control plan in case of fasteners covered by HTS, or • by means of rules to be established in the control plan in case the fastener is not covered by HTS	Specified in control plan	Specified in control plan	Specified in control plan
5	Coated steel parts • Cleaning/pre-treatment process data • Coating process data • Mass and/or thickness of coating	Specified in control plan	Specified in control plan	Specified in control plan	Specified in control plan

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for three dimensional nailing plates are laid down in Table 3.

Table 3: Tasks for the notified body

Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control				
Initial inspection of the manufacturing plant and of factory production control carried out by the manufacturer regarding the constancy of performance.	As defined in control plan	As defined in control plan	As defined in control plan	According to the control plan
Continuous surveillance, assessment and evaluation of factory production control				
Continuous surveillance, assessment and evaluation of the factory production control carried out by the manufacturer regarding the constancy of performance.	As defined in control plan	As defined in control plan	As defined in control plan	According to the control plan

4 Reference documents

EN 1995-1-1/A1:2008	Eurocode 5: Design of timber structures – General – Common rules and rules for building
EN 338:2016	Structural timber – Strength classes
EN 10111:2009	Continuously hot rolled low carbon steel sheet and strip for cold forming – Technical delivery conditions
EN 10088-1:2014	Stainless steels – List of stainless steels
EN 10088-2:2014	Stainless steels – Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes
EN 10346:2015	Continuously hot-dip coated steel flat products – Technical delivery conditions
EN 1993-1-1	Eurocode 3: Design of steel structures – General rules and rules for buildings
EN 1993-1-3	Eurocode 3: Design of steel structures – General rules – Supplementary rules for cold-formed members and sheetingEN 1998-1:2004 Eurocode 8: Design of structures for earthquake resistance – General rules, seismic actions and rules for buildingsEN 1999-1-1 Eurocode 9: Design of aluminium structures – General structural rules
EN 26891:1993	Timber structures – Joints made with mechanical fasteners – General principles for the determination of strength and deformation characteristics
EN ISO 8970:2010	Timber structures – Testing of joints made with mechanical fasteners – Requirements for wood density
EN ISO 6892-1:2016	Metallic materials – Tensile testing – Method of test at ambient temperature EN 1365-2 Fire resistance tests for loadbearing elements – Part 2: Floors and roofs EN 1380 Timber structures – Test methods – Loadbearing nailed joints
EN 1382:2016	Timber structures – Test methods – Withdrawal capacity of timber fasteners
EN 1383:2016	Timber structures – Test methods – Pull-through resistance of timber fasteners
EN 15129:2018	Anti-seismic devices
EN 12512:2001	Timber structures – Test methods – Cyclic testing of joints made with mechanical fasteners
EN 14592+A1:2012	Timber structures – Dowel-type fasteners – Requirements
EN ISO 1461:2009	Hot-dip galvanized coatings on fabricated iron and steel articles – Specification and test methods
EN ISO 2178:2016	Non-magnetic coatings on magnetic substances – Measurements of coating thickness – Magnetic method
EN ISO 1460:1995	Metallic coatings – Hot-dip galvanized coatings on ferrous materials – Gravimetric determination of the mass per unit area
EN ISO 2081:2018	Metallic and other inorganic coatings – Electroplated coatings of zinc with supplementary treatments on iron or steel
EN ISO 2177:2004	Metallic coatings – Measurement of coating thickness – Coulometric method by anodic dissolution
EN 13183-2:2002	Moisture content of a piece of sawn timber – Part 2: Estimation by electrical resistance method

EN ISO 7441:2015	Corrosion of metals and alloys – Determination of bimetallic corrosion in outdoor exposure corrosion tests
EN 13501-1:2018	Fire classification of construction products and building element – Part 1: Classification using data from reaction to fire tests
EN 13501-2:2016	Fire classification of construction products and building elements – Part 2: Classification using data from resistance to fire tests (excluding products for use in ventilation systems)

Annex A Principles for the static calculation of connections made with three dimensional nailing plates, with examples

1 Scope

This annex gives principles for, and examples of, the static calculation of connections made with three-dimensional nailing plates, with examples, in timber structures.

2 Introduction

The technical documents from manufacturers of three-dimensional nailing plates normally includes tables which show the product's load-carrying capacity for a particular nailing configuration. In calculations it is necessary to ensure that the proposed nailing configuration is in accordance with the manufacturer's assumptions, and that the static models assumed are in accordance with the proposed use in the timber structures.

3 Calculation principles

The basic principles for the calculation of connections with three-dimensional nailing plates are illustrated with some typical examples:

3.1 Beam to beam connection

Since there will normally be a gap between the two beams in the connection, the reaction force needs to be transferred by the angle brackets only, see Figure 1.

This method is applicable to thin steel plates since these result in low stiffness and yielding strength of the flanges for both torsion and plate bending.

In this way it is ensured, that each flange of the nailing plate will be subjected to a shear force very close to the corner.

If the force is positioned elsewhere, the torsional yielding strength would be exceeded, the nailing plate would yield resulting in the force ending in the corner.

The two groups of nails can be calculated independently of each other as eccentric loaded nailing plates where the ductility of the laterally loaded nails is utilised.

If the nailing plates are thick and hence have a large torsional stiffness and load carrying capacity, there will be a risk of withdrawal of the nails or screws causing a progressive failure (a zipper like failure).

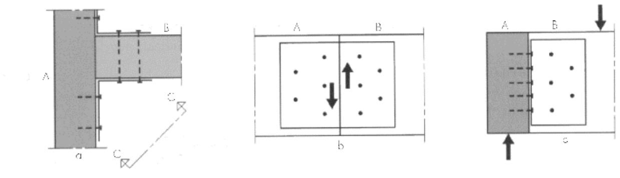


Figure 1 - Beam to beam connection. Connection with two angle brackets and nails or screws.

a = plan; b = view on c-c (expanded); c = elevation; A = Cross beam; B = Beam

This simple static model may be refined by allowing for the occurrence of torsion in the thin steel plates and withdrawal forces in the fasteners.

In this case the load-carrying capacity of the fasteners shall be verified for a combination of actual and lateral force.

3.2 Purlin with purlin anchors

In this example, shown in Figure 2, an analysis of a purlin connected to a beam with purlin anchors is carried out.

The illustration shows how the design of the structure influences the actions on the nailing plates.

It is assumed that the resulting force from the loading case “wind suction on the roof” acts in the middle of the purlin.

The ability of the roof cladding to move the resulting wind force due to extra tensile force in the nail or screw and contact pressure between the purlin and the cladding is disregarded, this assumption is reasonable for thin corrugated roof sheets with screws in the middle of the purlin.

As in the former example it is assumed that the force transfer in the nailing plate corresponds to a shear force in the corner of the nailing plate.

If the purlin anchors are placed on the same side of the purlin (Figure 2 upper drawing) equilibrium requires that the nail group in the beam is able to carry the eccentricity moment from the force in the middle of the purlin.

If the purlin anchors are placed diagonally in relation to the purlin (Figure 2 lower drawing) the eccentricity moment will be much smaller, however, if the purlin is subjected to a torsional moment, it does not normally present any problems.

If two purlin anchors are used per connection, as shown on the dotted nailing plate in the section in Figure 2 it is possible to obtain equilibrium by the inclined forces in the nails in the beam.

In this way the nail groups are subjected to a central force without any large withdrawal forces in the nails.

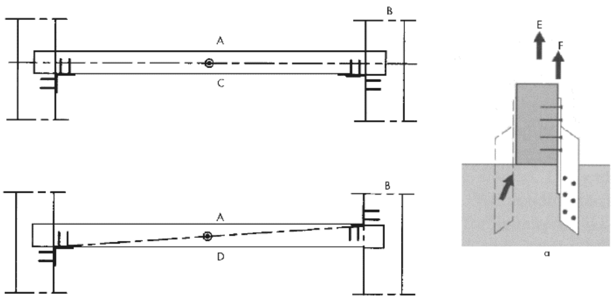


Figure 2 - Anchoring of a purlin by means of purlin anchors and nails

a = section; A = Purlin; B = Beam; C = Purlin anchors placed on the same side; D = Purlin anchors placed diagonally; E = Suction, purlin anchors placed on the same side; F = Suction, purlin anchors placed diagonally

3.3 Purlin with angle brackets

In this example a purlin is analysed for a lifting force and connected to an underlying beam with angle brackets.

The photo in Figure 3 illustrates the static behaviour of the angle brackets and the nails which are subjected to withdrawal forces.

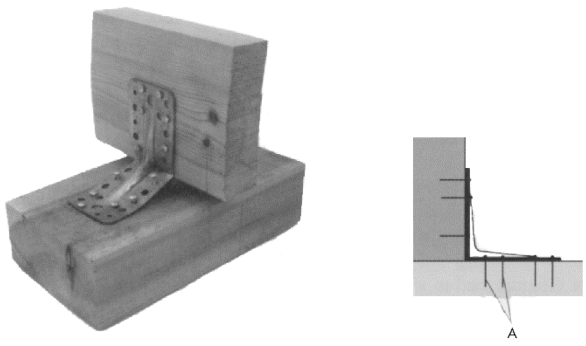


Figure 3 - Failure in a connection with an angle bracket and annular ringed nails subjected to a lifting force.

Only the inner nails, which are pulled out successively, are active.

A = Force transfer

Only the inner nails are active; the outer nails are not subjected to a withdrawal force, as a yielding hinge is formed in the thin flange of the bracket.

(Stiffer and stronger angle brackets exist where nails are simultaneously active for withdrawal.)

A single bracket subjected to a lifting force as shown in Figure 4 transfers the forces by axial tension in the nails near the vertical flange and by contact compression near the free edge of the horizontal flange.

The necessary expressions for the determination of the withdrawal force are given in Figure 4.

The eccentricity *e* is given as the distance from the action line of the force, and a_c is a small length.

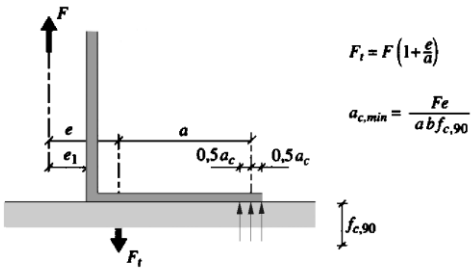


Figure 4 - Angle bracket subjected to a lifting force.
The withdrawal force can easily be found from the expressions when the small length a_c is estimated. Symbols are defined in Eurocode 5.
B = Width of bracket

If one angle bracket is considered, withdrawal forces in the nails in the horizontal flange are calculated using e_1, which corresponds to half the width of the purlin (unless it can be demonstrated that the roof covering affects the line of action of force F).

In the vertical flange the nails shall be able to transfer the moment F_{e1} together with the lateral load *F.*

Where the nails are placed in a row, an assessment has to be made of the extent the nails act together in transferring axial forces.

In this case the distances between the nails, the stiffness of the bracket as well as the axial stiffness of the nails and possibly the forming of a yielding hinge have to be considered.

For the connection shown in Figure 3 tests show that it is not possible to take account of more than two closely spaced rows of annular ringed nails acting together to transfer the axial withdrawal force.

In Figure 5 two connections with angle brackets are shown, where it is possible to find an estimate of the active forces, which is close to reality.

In both cases the vertical force is distributed evenly over the nails in the vertical flange.

If two angle brackets are considered (or diagonally positioned, see clause 3.2) the calculation of withdrawal forces in the nails in the horizontal flange may be undertaken with e = o.

The shifting of position of the force F gives a moment in the vertical flange as indicated in the diagrams over the forces and the internal moments - but in practice this can be disregarded.

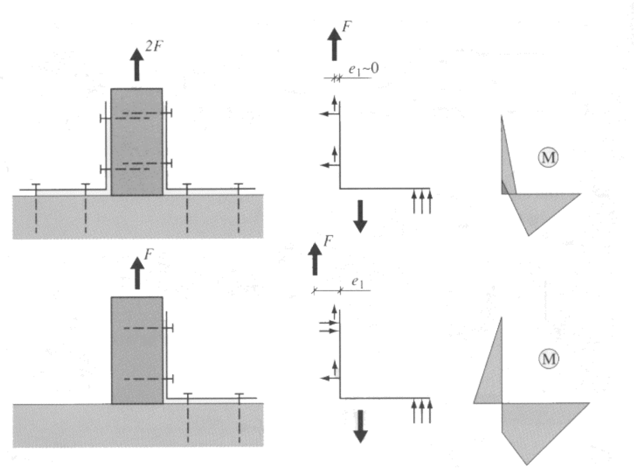


Figure 5 - Connection with double and single angle brackets.
Internal forces and moments in the bracket.

3.4 Transfer of forces by contact compression stresses

When a force is transferred by contact stresses between the nailing plate and the timber member, bending will always occur in the nailing plate.

Plate bending can best be modelled by the theory of plasticity, which is covered in clause 4.

A good (and safe) estimation of the load carrying capacity can be obtained by assuming that the contact stress is equal to the compression strength of the wood perpendicular to the grain $f_{c,90}$ and that it is placed within the given geometry resulting in the largest load-carrying capacity.

The compression strength $f_{c,90}$ for the relatively small contact area can be increased as described in the revision to Eurocode 5.

For the joist hanger with sharp edge timber in Figure 6 the loaded width *a* can be found from moment equilibrium, since the yielding plate moment of the nailing plate is known to be m_y (per length unit).

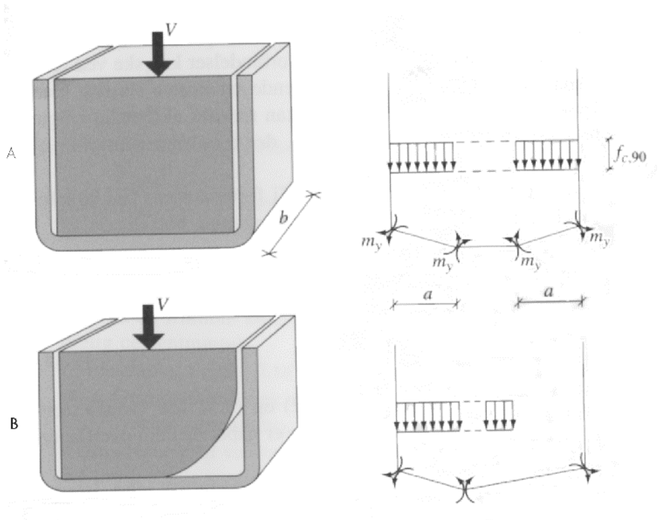


Figure 6 - Contact compression stress at the bottom of a joist hanger.

A = Sharp edge timber; B = Timber with wane

$$2m_y = \frac{f_{c,90}a^2}{2}$$

$$a = 2\sqrt{\frac{m_y}{f_{c,90}}}$$

where equilibrium in the direction of the shear force results in

$$V = 2ab \cdot f_{c,90} = 4b\sqrt{m_y \cdot f_{c,90}}$$

It is assumed that the yielding moment is the same at the bottom and the sides of the joist hanger, and that they have the same width *b*.

Where this is not the case, e.g. where different plate thicknesses are used in a welded joist hanger, it is simple to take this into account.

If the timber does not have sharp edges at the support, this will result in another (less favourable) load distribution, see the lower drawing in Figure 6.

4 Plastic design principles

This section deals with plane connections with fasteners for which the force-deformation relation can be assumed to be perfect plastic i.e. with a horizontal force deformation relationship.

Only statically determinate connections are treated, but extending the philosophy to statically indeterminate connections is not difficult.

For simplicity only two-dimensional nailing plates are considered although these are outside the scope of the ETAG but three dimensional solutions may frequently be modelled by two dimensional considerations.

It is assumed that the force-deformation relation of the fasteners is rigid-plastic, but the expressions are also applicable to elastic perfectly plastic fasteners, when it can be demonstrated, that all fasteners considered are on the perfectly plastic (i.e. the horizontal) part of the force-deformation relation.

For a connection with plastic fasteners one can calculate an upper bound and a lower bound for the exact plastic load carrying capacity.

Frequently it is harder to determine the latter, and since it is relatively easy to find an upper bound, which is close to the exact plastic capacity, one can frequently be satisfied with an upper bound.

4.1 Determination of an upper bound

An upper bound of the load carrying capacity of a connection can be determined in the following way:

- a rigid body deformation is assumed;
- it is assumed that the force in a fastener is equal to the yield force and that the direction of the force is equal to the direction of the relative deformation;
- an upper bound of the plastic load carrying capacity is calculated by putting the internal work W_{inner} of the fasteners equal to the external work W_{ex} of the external force. (The principle of Virtual Work).

Frequently it is convenient to describe the rigid body motion as a rotation about an estimated rotation centre.

As a guide for the estimation the exact centre of rotation is often situated close to a line perpendicular to the external force R through the elastic centre of gravity of the connection, see Figure 7.

The centre of rotation often lies opposite the force R in relation to the centre of gravity; the bigger the eccentricity the closer to the centre of gravity.

The virtual rotation is denoted θ. With the symbols in Figure 7 the internal work and the external work can be found from:

$$W_{inner} = \sum_{i=1}^{n} \theta r_i F_y$$

$$W_{ex} = \theta e R$$

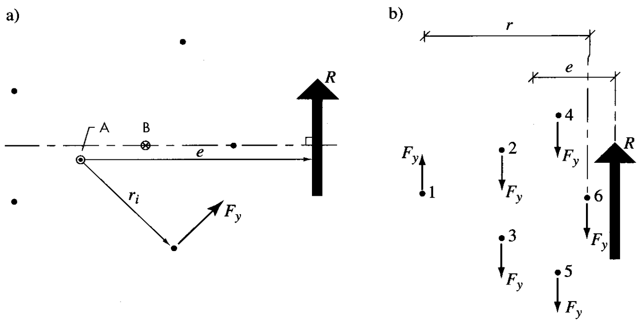


Figure 7 - Determination of upper bound (a) and lower bound (b).

The yield force of a fastener is denoted F_y.

A = estimated centre of rotation; B = Centre of gravity.

The upper bound denoted as R^+ can be calculated from

$$R^+ = \frac{\sum_{i=1}^{n} \theta r_i F_y}{\theta e} = \frac{\sum_{i=1}^{n} r_i F_y}{e} = \frac{F_y}{e} \sum_{i=1}^{n} r_i \qquad (1)$$

Equation (1) can be perceived as a moment equilibrium equation about the estimated centre of rotation.

The following examples show, that R^+ will only be slightly larger than the exact value provided a reasonable centre of rotation is employed.

It is assumed for the plastic calculation, that all fasteners contribute together with their full yielding force.

This requires that the slip at the fasteners close to the centre of rotation is so large, that the yielding force has been reached.

The fasteners far away from the centre of rotation can be subjected to large slips, which finally can be so large that failure will occur.

Where splitting will not occur, based from experience in tests, one can normally assume that

$$u_{failure} = 4u_y$$

where:

$u_{failure}$ = the slip (relative displacement) at failure;

u_y = the slip at the beginning of yielding.

Therefore, it will normally be a conservative estimate to disregard the fasteners, which have

$$r \leq 0{,}25\ r_{max}$$

where r = distance to the centre of rotation;

r_{max} = the maximum distance for a fastener from the centre of rotation (see Figure 7).

The reduction of the load carrying capacity of the connection will normally be insignificant, and in practical calculation this is often disregarded.

4.2 Determination of a lower bound

A lower bound of the load carrying capacity of a group of plastic fasteners can be determined by estimating a force distribution over the fasteners in a way that the equations of equilibrium are fulfilled (i.e. a static allowable force distribution), and that the force in every single fastener is less than or equal to the yield force (i.e. a secure force distribution).

4.2.1 Example of the determination of a lower bound

As an example the lower bound of the connection shown in Figure 7b is determined.

It is assumed that some of the fasteners give equilibrium in the direction of the force, (fasteners 2-5) and that the others give moment equilibrium, (fasteners 1 and 6).

The easiest way to set up the moment equilibrium is by taking moment about the resultant of the fasteners providing force equilibrium, (fasteners 2 - 5).

The distance between this resultant and R is denoted as e in the figure.

A lower bound, R^- , of the load carrying capacity of the connection is given by:

$$R^- = \min\left\{4F_y, \frac{r}{e}F_y\right\}$$

It should be noted that with the estimated force distribution shown in Figure 7b equilibrium perpendicular to the outer force is fulfilled automatically, since all forces are assumed parallel to this.

4.3 Plastic calculation examples

4.3.1 Example 1

This example concerns the plastic load carrying capacity of a fish plate connection in a truss cord shown in Figure 8 where the 14 nails connect the end of the fish plate to the cord.

It is assumed that $N = 2V$.

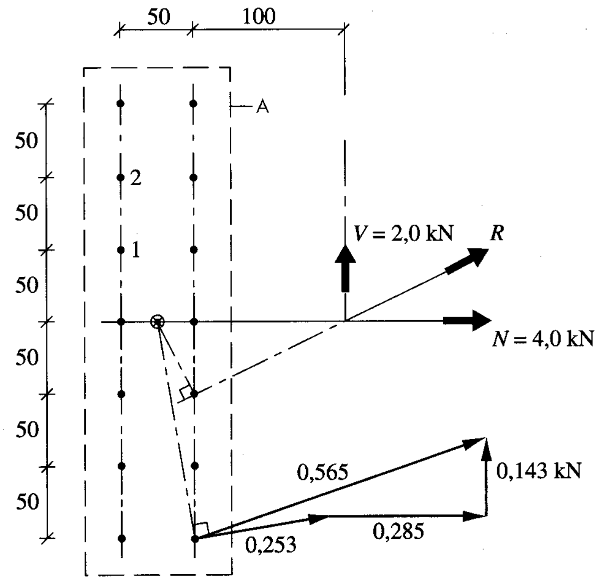


Figure 8 - Nail connection subjected to an eccentric force.

All dimensions in mm.

A = Boundary of fictitious continuous layer; B = Centre of gravity

The elastic load carrying capacity from proportional calculation has been determined as

$$V = 0{,}58/0{,}565 \cdot 2{,}0 = 2{,}05 \text{ kN}$$

where:

0,58 = design load-carrying capacity of the nail;

0,565 = calculated design force (see Figure 8).

Equation (1) is applied to calculate an upper bound of the load carrying capacity of the perfectly plastic connection. It is assumed that the centre of rotation is situated in nail number 1.

$$\Sigma r_i = 2\ (50 + 100) + 150 + 200 + 50 + 2\ (71 + 112) +$$

$$+ 158 + 206 = 1430 \text{ mm}$$

By measuring or calculation, e = 112 mm, and equation (1) results in

$$R^{+} = \frac{0{,}58 \cdot 1430}{112} = 7{,}41 \text{kN}$$

which is equivalent to

$$V^{+} = 7{,}41/\sqrt{5} = 3{,}31 \text{kN}$$

If the centre of rotation is assumed to be at nail number 2, one finds V^{+} = 2,86 kN, which is close to the exact load carrying capacity of 2,81 kN, determined from an iterative calculation.

A lower bound of the load carrying capacity of the perfectly plastic connection can be determined by assuming, that the forces in the middle 10 nails are parallel to R, and that the forces in the outer 4 nails are perpendicular to the radius from the centre of gravity.

With this force distribution equilibrium perpendicular to R is fulfilled; it is statically allowable.

Requiring that the forces in the nails shall be less than or equal to the yielding force one gets:

$$R^{-} = V^{-} \cdot \sqrt{5} \leq 2 \cdot 5 \cdot 0{,}58 \qquad V^{-} \leq 2{,}59 \text{ kN}$$

$$M^{-} = V^{-} \cdot 125 \leq 4 \cdot 153 \cdot 0{,}58 \qquad V^{-} \leq 2{,}84 \text{ kN}$$

So, the load carrying capacity of the perfectly plastic connection is limited by

$$\sqrt{5} \cdot 2{,}59 \leq R_y \leq \sqrt{5} \cdot 2{,}86 \text{ kN}$$

4.3.2 Example 2

Figure 9 shows a fish-plate subjected to a shear force with a direction as shown.

A force distribution is assumed, where the force in all nails is parallel to the line connecting the centres of gravity and with a magnitude equal to the yield force.

Equilibrium perpendicular to *V* is ensured by the contact force F_c between the ends of the beams.

Friction is disregarded.

$$V^{-} = 2 \cdot 10 \cdot 0{,}73 \cdot \cos\alpha = 11{,}7 \text{ kN}$$

Since the estimated force distribution can be achieved by a set of translations and rotations of the members connected, forming a geometric possible deformation field, this force is also an upper bound, i.e. it is an exact plastic solution.

If the shear force changes direction, the system will change, because equilibrium can no longer be achieved by the contact pressure.

The nail groups will be subjected to an eccentric load *V*.

The plastic load carrying capacity V_y has been calculated as 10,6 kN.

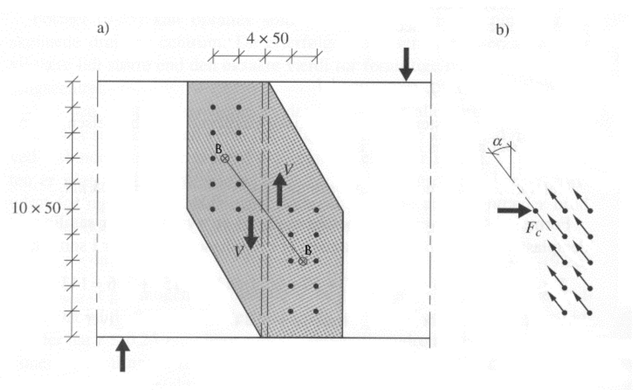


Figure 9 - Connection with a fish-plate on each side.

Ten nails 31/80 per group with a design load carrying capacity of 1,25 · 0,58 = 0,73 kN per nail, per shear plane (Factor 1,25 for steel to wood).

B = Centre of gravity

4.3.3 Example 3

This example deals with a gusset plate connection. It is assumed that there is a good fit between the timber members, i.e. the joint is small with nails as fasteners distributed evenly and with the same number *n* in each group.

The rotation will press the top chord and the bottom chord together, so a contact force will emerge in the joint.

Figure 10 shows the forces and deformations after yielding in the nails has developed.

Friction in the joint is disregarded, and it is approximated that each nail group is loaded centrally with a force *F*.

Further, it is assumed that the component of *R* perpendicular to the joint results in a contact force.

By projection it can be found, that *F* can be expressed by R_{par}, which is the component of *R* parallel to the joint.

$$F = R_{par} / \cos(\alpha + \beta)$$

where the angle *β* has been determined from frame analyses and it can approximately be determined from

$$\tan\beta = 0{,}2/(0{,}7 \cdot l/h - 0{,}3 \cdot \cot\alpha)$$

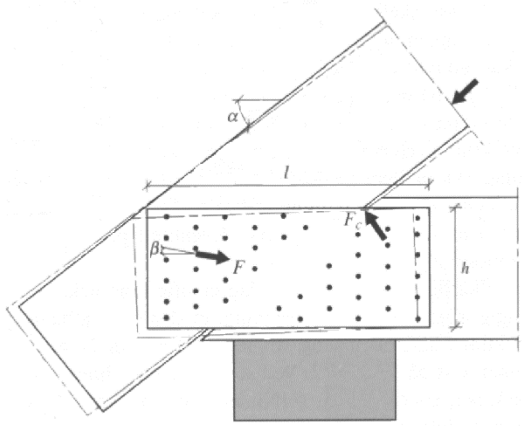


Figure 10 - Gusset plate connection between top chord and bottom chord.

There is a good fit, so a contact force emerges in the deformed shape shown with dotted lines, the forces acting on the top chord are shown with arrows. The thickness of the gusset plate is *b*.

The strength of the gusset plates should be verified for a tensile force F_t or a shear force F_v.

$$F_t = \frac{R_{par}}{\cos\alpha} \leq A_{gusset} f_t \qquad \text{for} \qquad \tan\alpha \leq \frac{f_v}{f_t}$$

$$F_v = R_{par} \leq \frac{A_{gusset}}{\sin\alpha} f_v \qquad \text{for} \qquad \tan\alpha > \frac{f_v}{f_t}$$

where:

A_{gusset} = cross sectional area *b h*.

By verification of the shear strength a failure plane parallel to the joint should be used.

This description of calculation methods for plastic plane connections can be utilised for the static analysis of three dimensional nail plate connections where the internal forces are transferred in the plane of the thin plates of the brackets.

The beam to beam connection shown in Figure 1 is a typical example.

Annex B Method of testing three-dimensional nailing plates with examples

1 Scope

This annex gives methods of testing three-dimensional nailing plates with examples when used to join end grain to side grain (Figure 1) and side grain to side grain (see Figures from 2 to 6) of timber members, and specifies the form and dimensions of the test specimens.

The general testing procedures are detailed in clause 2.2.1.

2 Timber members

The timber members shall have the depth and width specified by the manufacturer.

3 Test specimen

Examples of test specimens used to determine load and slip characteristics are shown in Figures 1 to 6.

The specimen shall include gaps and wane as appropriate, as described in clause 2.2.1.

For end grain to side grain joints the side grain member may be either fully restrained against rotation or simply supported as specified by the manufacturer.

If specified, lateral restraint may be applied to the end grain member.

4 Expression of results

The modified load carrying capacity of each individual test result shall be calculated from the following formula. If the load carrying capacity is governed by fastener withdrawal:

$$F_{max,\,mod} = F_{max}\left(\frac{\rho_k}{\rho}\right)^{c_w}$$

or, if the load carrying capacity is governed by tensile failure of the fastener then:

$$F_{max,\,mod} = F_{max}\left(\frac{F_{t,k}}{F_t}\right)$$

or if the load carrying capacity is governed by tensile failure of the three-dimensional nailing plate:

$$F_{max,\,mod} = F_{max}\left(\frac{f_{t,k}}{f_t}\right)\left(\frac{t_{ef,k}}{t_{ef}}\right)$$ or, if the load is governed by shear of the fastener:

$$F_{max,\,mod} = F_{max}\left(\frac{\rho_k}{\rho}\right)^{c_s}\left(\frac{M_{y,k}}{M_y}\right)^{0.5}\left(\frac{d_d}{d}\right)^{0.5}$$

or, if the load carrying capacity is governed by bending of the steel plates and contact compression

$$F_{max,\,mod} = F_{max}\left(\frac{\rho_k}{\rho}\right)^{0.5}\left(\frac{M_{y,k}}{M_y}\right)^{0.5}$$

Note - Shear and moment failure are not considered.

where:

F_{max} = maximum load of an individual test result on the three-dimensional nailing plate connection, in Newtons;c_s; c_w = are non-dimensional parameters.

Note - In the absence of other information, the following values may be used, depending on the method used for selecting the timber densities in accordance with EN 28970:

	EN28970 Method	
	1	2
c_w	0	2
c_s	0	0.5

ρ = actual density of the timber member in which the failure took place, in kilogrammes per cubic metre;

ρ_k = characteristic density of the timber grade to which the test results shall be applied in kilogrammes per cubic metre;

F_t = actual tension capacity of the fastener in Newtons;

$F_{t,k}$ = characteristic tension capacity of the fastener in Newtons;

f_t = actual tensile strength of the three-dimensional nailing plate material, in Newtons per square millimetre;

$f_{t,k}$ = characteristic tensile strength of the three-dimensional nailing plate material, in Newtons per square millimetre;

Note - The value of $f_{t,k}$ is the value given as R_m in EN 10088-2 (for stainless steels) or in EN 10147 (for hot-dip zinc-coated structural steel).

t_{ef} = actual thickness of the three-dimensional nailing plate, reduced by the thickness of the coating, in millimetres;

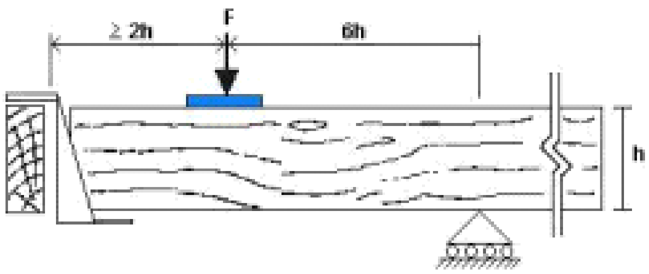
$t_{ef,k}$ = nominal thickness (reduced by the thickness of the coating)of the three-dimensional nailing plate, in millimetres;

d = actual diameter of fastener;

d_d = design diameter of fastener;

M_y = actual fastener yield moment tested in accordance with EN 409;

$M_{y,k}$ = characteristic fastener yield moment tested in accordance with EN 409 or calculated in accordance with Eurocode 5.



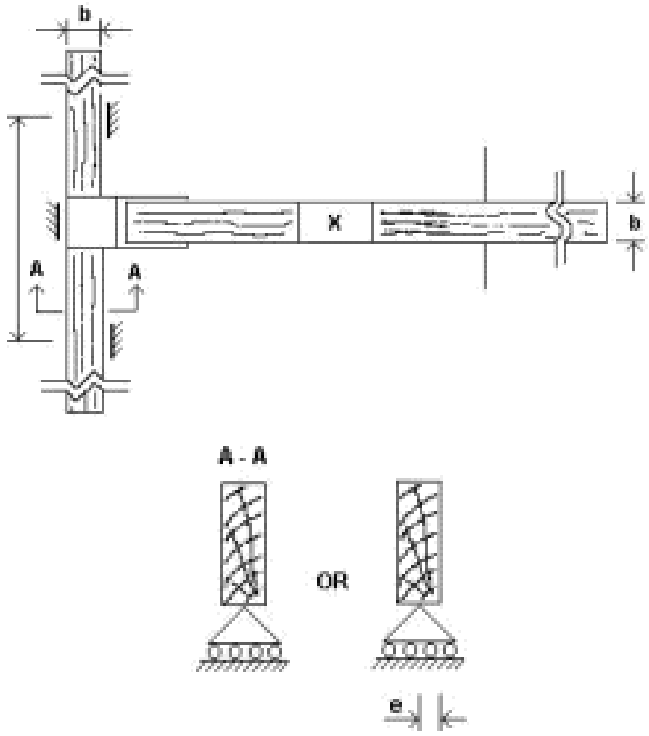


Fig. 1 End grain to side grain

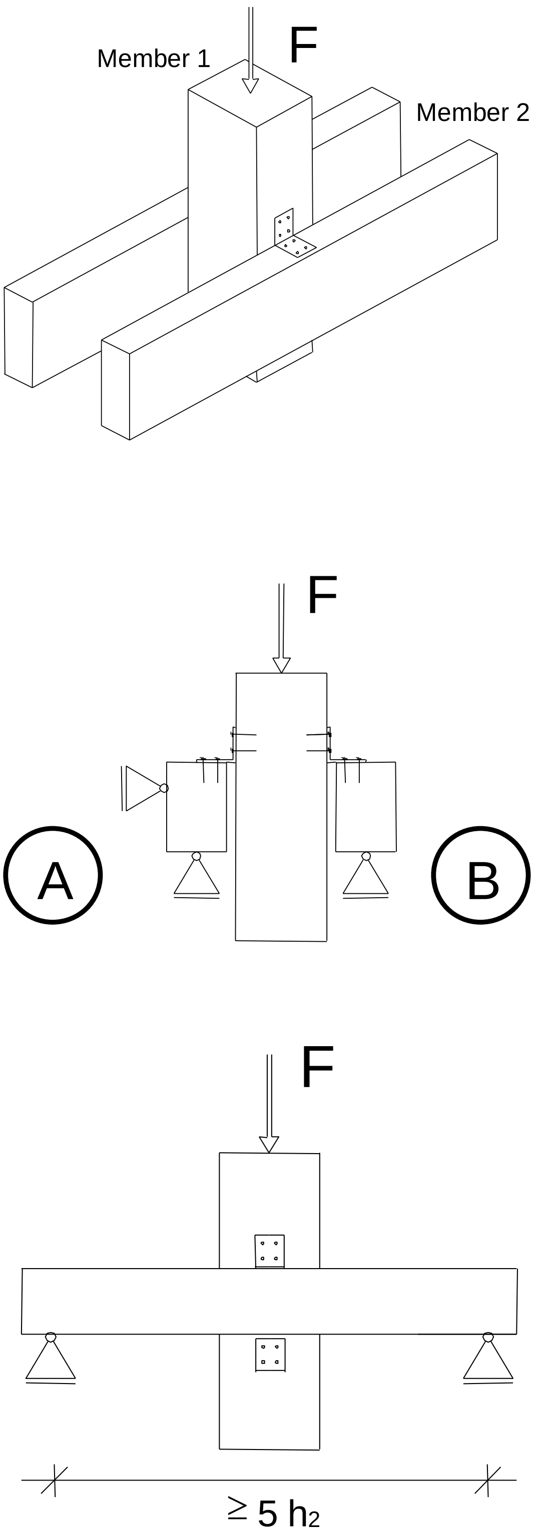


Fig. 2 – Symmetrical side grain to side grain

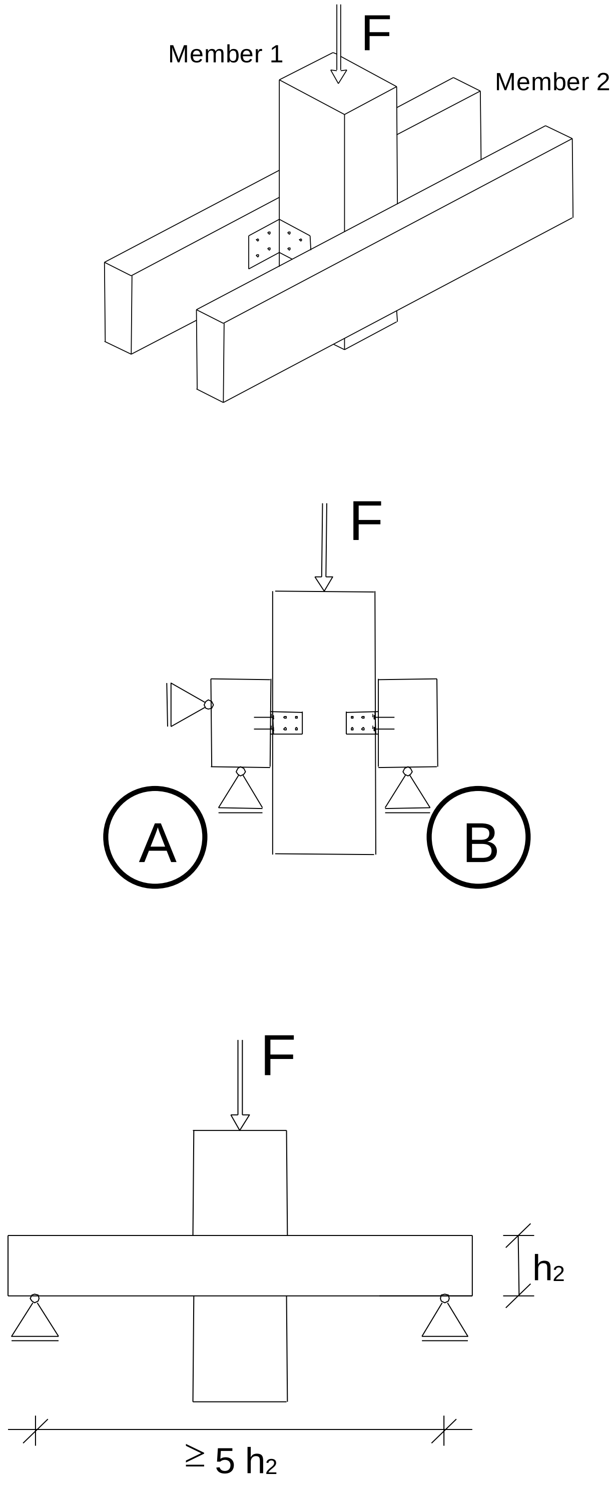
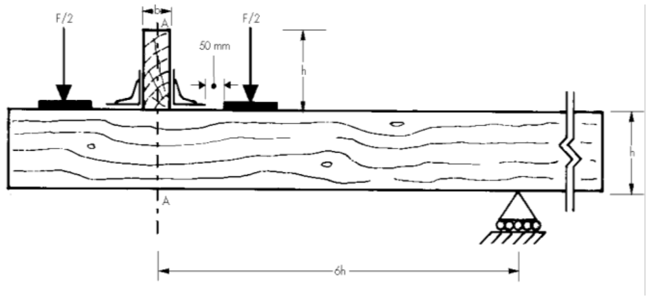


Figure 3 Symmetrical side grain to side grain



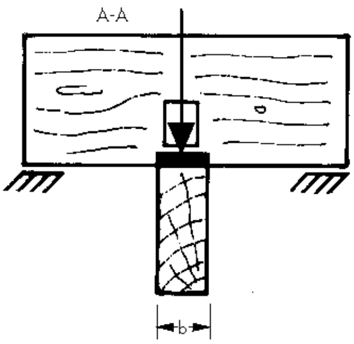


Fig. 4 – Side grain to side grain

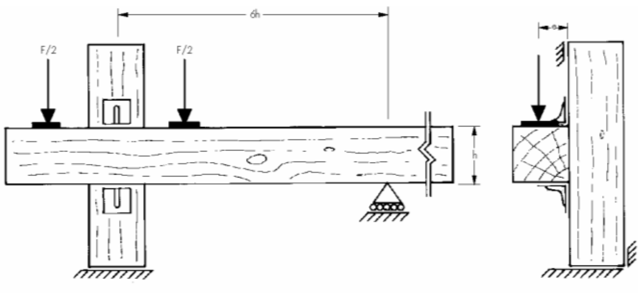


Fig. 5 – Side grain to side grain

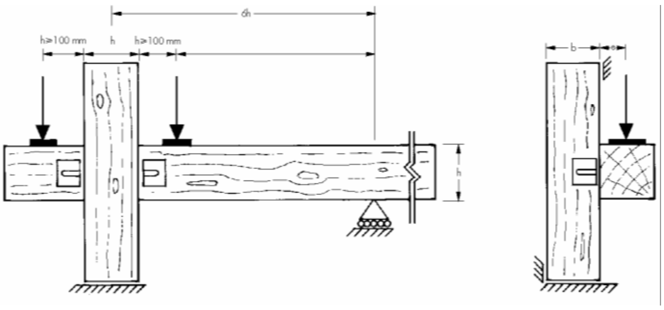


Fig.6 Side grain to side grain