Module: Timber Connections

Unit: Metal connectors

Level: Introductory

Learning Resources Modules:

This unit covers the following topics:

- **Metal plate fasteners**
- **Connectors with bolts**

Introduction

There are four criteria designers should take into account when selecting and detailing connections for a particular application:

- load transfer (stiffness, ductility, robustness and differential movement consideration)
- appearance
- fire resistance
- durability.

The traditional mechanical fasteners for structural timber connections are divided into two groups depending on how they transfer the forces between the connected members – 'dowel-types' and 'metal connectors'.

Metal fasteners have negligible fire resistance and absorb and transfer heat quickly. Fire protection with plasterboard is the most common solution.

Metal fasteners are efficient but the relative weakness of the timber itself remains the governing factor.

The appearance of the metal fasteners is not very important as most are concealed within the connection. However, careful detailing is needed if the architect wishes to expose the connection.

The strength and stiffness properties of these engineering hardware products are most commonly derived through testing.

Two main types of metal connectors can be identified:

- metal plate fasteners
- connectors with bolts.

Metal plate fasteners

Metal plate fasteners can be divided into two categories:

- Two-dimensional plates – ie punched metal plates or nail plates used to join two or more pieces of timber of the same thickness in the same plane
- Three-dimensional nail plates such as joist hangers, framing anchors, truss clips and wall ties.

Metal plate connectors rely on a number of nails or other doweltype fasteners.

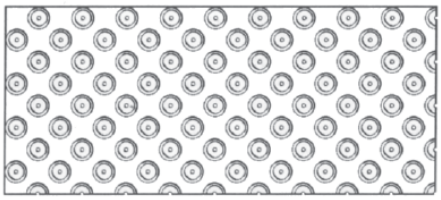

Figure 1: 2D nail plate with nails

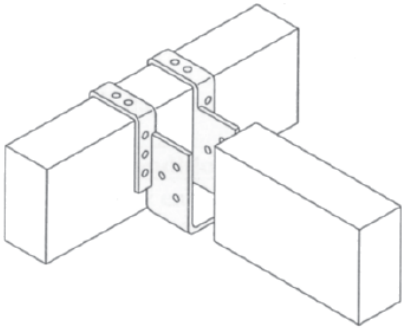

Figure 2: Joist hanger for principal beam (shear)

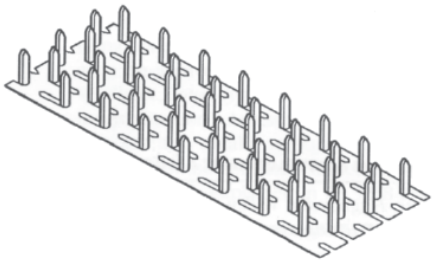

Figure 3: 2D punched metal plate fastener with teeth

Two-dimensional (2D) plates

There are two main types of two-dimensional (2D) plates:

- Two-dimensional (2D) nail plates
- Two-dimensional (2D) punched metal plates.

2D nail plates have preformed holes for nails. Manufacturers recommend the use of improved nails such as square twisted types driven into these plates in order to fit tightly into the plate holes.

These plates are normally used in factory prefabrication rather than on site. Using these plates can transfer member forces with smaller connection areas than are possible with hand-nailed plates. Two-dimensional (2D) nail plates are widely used for in-plane joints such as trussed rafters.

Nail plates are manufactured from a strip of typical thickness normally around 1mm.

Three-dimensional (3D) plates

Three-dimensional (3D) plates have been manufactured by bending nail plates into various shapes. Examples using such 3D plates are joist hangers, truss clips and brace anchors. There are a range of 'off-the-shelf' components available from a number of manufacturers.

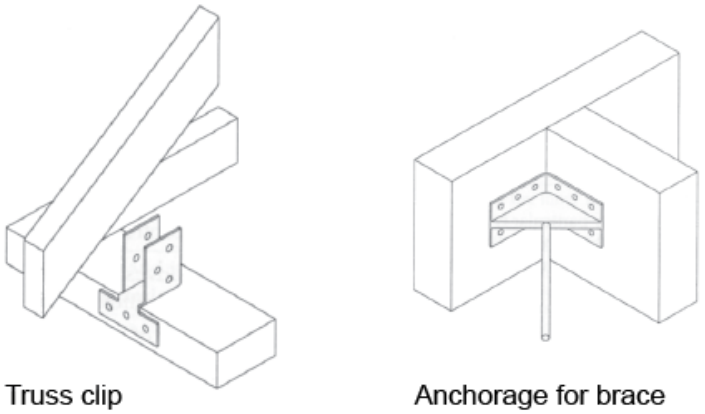

Figure 4: Truss clip (shear) and anchorage for brace (tension)

Although the strength and stiffness properties of engineering hardware products are most commonly derived through testing, until recently there has been little standardisation in the industry for three-dimensional (3D) plates.

Currently ETAG 015 *Guideline for European technical approval of three-dimensional nailing plates* is used to derive test values for 3D plates as there is no British nor European Standard for testing/assessing three-dimensional nailing plates for timber-to-timber joints. These test data may be used to calculate characteristic design values for use with Eurocode 5 design procedures.

Lack of control on site and lack of understanding on the part of site operatives may result in timber engineering hardware being inadequately fixed. For instance plasterboard nails, allegedly, are often used on site instead of the improved nails specified by the manufacturers for fixing timber engineering hardware, as well as insufficient nails being used on metal plates.

2D punched metal plates have integral projections punched out in one direction and bent perpendicular to the base of the plate. They are generally manufactured from a strip of 0.9mm to 2.5mm thickness. These 2D punched metal plates are suited to factory

prefabrication and are able to transfer member forces with smaller connection areas than are possible with hand-nailed plates. They are widely used for in-plane joints such as trussed rafters where they have largely replicated the nail plates.

With 2D punched metal plates, the load is transferred from the timber member into the plate teeth, then from the teeth into the steel plate and across the joint interface, then back down into the teeth in the other member. In a connection two such plates are fixed on opposite faces of the members. Since the joints are flexible out of plane, extra care should be taken in handling such components as they can be damaged during handling and erection.

Design and manufacturing specification for 2D punched metal plates is described in Eurocode 5 section 8.8 and BS EN 14250. 2D punched metal plates are designed with a variety of nailing patterns, nail lengths and nail shapes. Usually, specialist fabrication companies use computer-aided design packages for the manufacturing process. (Additional information will be found in PD 6693-1-1 *Guidance to Eurocode 5*, which is yet to be published.)

Characteristic plate strength properties should be established from standard tests whose basis is given in BS EN 1075 and those properties should be used in Eurocode 5 formulae for predicting the strength of such joints. For joint slip calculations Eurocode 5 section 7 should be followed.

Connectors with bolts

Connections made with metal connectors gain the maximum performance from the bolts. However, spacing rules could impair overall efficiency. These connections are mostly demountable.

Eurocode 5 mentions three types of bolted connectors and their design methods. They are:

- split-ring connectors
- shear-plate connectors
- toothed-plate connectors.

Refer to BS EN 912 for specifications. For these connectors Eurocode 5 rules for the design of joints using bolted timber connectors, together with guidance on appropriate edge and end distances, should be followed. The timber section removed for the bolts and connectors should be taken into account and it is important to assess the effective cross-sectional area when a design is carried out. This is explained in Eurocode 5. There is considerable overlap in the behaviour and applications of the three types of connectors.

There are some instances in which two different connectors are used in one connection – ie split-rings and double-sided toothed-plates and shear-plates and single-sided toothed-plates. In split-ring and double-sided toothed-plate joints, load is transferred directly between the surfaces of the members that are in contact. This assembly can be done on site. Shear-plates and single-sided toothed-plates are suitable for steel-to-timber joints as well as for timber-to-timber joints. These joints are pre-fabricated and only the bolts are installed on site. For this connection the load transfer is achieved by the bolt, which is stressed in shear by bearing contact with the connector plates.

These connections are labour intensive and can therefore be expensive compared with other methods. They are usually used for timber repairs.

Split-ring connectors (split-rings)

Split-ring connector units consist of one split-ring with a bolt, washers and nut, and the ring itself may be of parallel or bevel-sided form. The bevel-sided form is usually the easier to insert and gives greater load capacity, although Eurocode 5 does not

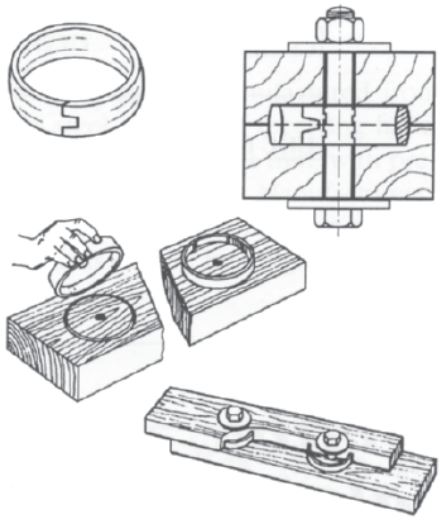

Figure 5: Split-ring connectors

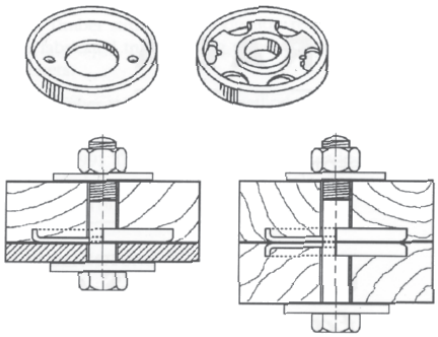

Figure 6: Shear-plate connectors

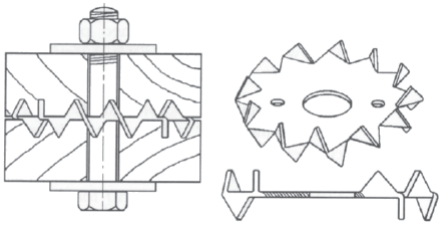

Figure 7: Toothed-plate connectors

distinguish between the two in recommending basic loads. Usually split-rings are formed from steel, aluminium cast alloy or cast iron. They are circular, with diameters from 60mm to 260mm, and are placed in pre-cut grooves produced by rotary cutters.

Split-ring connector joints are used in laterally loaded timber-to-timber connections. Connection strength depends on timber and connector dimensions, spacing, end distances and density of the timber. However connection stiffness depends mainly on the connector diameter and the timber density.

In split-ring connectors, the load is transferred from one timber member to another through embedding stresses via the split-ring connector. The connected member must also offer adequate shear resistance. Joint slip needs to be considered in designs for split-ring connectors. For the correct installation and better performance, precise grooving and boring is essential.

Eurocode 5 section 8.9 explains the connection design method for split-rings.

Shear-plate connectors

Shear-plate connector units consist of one shear-plate with a bolt, washers and nut. Shear-plates are also formed from steel, aluminium cast alloy or cast iron as split-rings. They are circular, with diameters from 60mm to 260mm, and are placed in pre-cut grooves produced by rotary cutters.

Shear-plate connector joints can be applied in steel-to-timber connections as well as timber-to-timber connections. They are used in laterally loaded joints as with split-rings. Shear-plate connectors are normally installed before the assembly of the structure, although the joints are demountable.

Connection strength depends on timber and connector dimensions, spacing, end distances and density of the timber. However connection stiffness depends mainly on the connector diameter and the timber density.

In shear-plate connectors, after the transfer of the load into the connector, the bolt is loaded through bearing stresses between the shear-plate and the bolt. The load is then transferred through the shear resistance of the bolt and thereafter to the second shear-plate or a steel member. In shear-plate connections the diameter of the hole in the shear-plate consequently corresponds to the bolt diameter plus a small tolerance. Due to this tolerance, a considerable initial slip can be expected in shear-plate connections. Joint slip needs to be considered in designs using these connectors. For the correct installation and better performance precise grooving and boring is essential.

Eurocode 5 section 8.9 explains the connection design method for shear-plate connectors.

Toothed-plate connectors

Toothed-plate connectors are normally held together by bolts. They are made from cold-rolled uncoated low-carbon narrow steel strips or hot-dipped galvanized mild steel. They are available in a variety of shapes and sizes, with diameters ranging from 38mm to 165mm. However, much larger connectors are available for use in glued laminated members. Toothed-plate connectors are mostly circular, but square and oval shapes are also available.

With toothed-plate connectors, bolts are tightened in order to press the teeth into the timber.

Bolts are installed with round or square washers of a size about half the diameter of the connectors used. They could be unsuitable for denser timbers, as it can be difficult to press in the teeth. Usually they cannot easily be used for timber or wood-based panel products with a characteristic density of more than about 500 kg/m^3.

Double-sided toothed-plate connector joints are used in laterally loaded timber-to-timber connections. Single-sided toothed-plate connector joints can be used in laterally loaded steel-to-timber connections and in demountable timber-to-timber joints.

Connection strength mainly depends on connector and timber dimensions and load-carrying capacity of the bolt. However connection stiffness depends mainly on connector diameter and the timber density. For small connector diameters, up to 65mm mild steel bolts are satisfactory. If bolts are used to press the connector teeth into the wood, large washers are required due to high stresses perpendicular to the grain and the consequent crushing of the timber. High-strength bolts with toothed-plate connectors can be replaced by permanent mild steel bolts using washers normal for timber structures.

The load is transferred from one timber member to the other through embedding stresses into the teeth of the connector, through the plate and into the teeth on the opposite side, in a double-sided toothed-plate connection.

In toothed-plate connector design, joint slip is negligible. However, in single-sided connections, the load is transferred into the toothed-plate then via shear in the bolt into either the steel member or the second toothed-plate – therefore more slip is possible.

In toothed-plate connectors the diameter of the hole in the toothed-plate consequently corresponds to the bolt diameter plus a small tolerance that causes initial slip.

Eurocode 5 section 8.10 explains the connection design method for toothed-plate connectors.

Relevant Standards

BS EN 1995-1-2004+A1:2008 *Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings*

BS EN 1075:2000 *Timber structures – Test methods – Joints made with punch metal plate fasteners*

BS EN 912:2000 *Timber fasteners – Specifications for connectors for timber*

prEN 14545 *Timber structures – Connectors – Requirements*

BS EN 28970:1991 ISO 8970:1989 *Timber structures – Testing of joints made with mechanical fasteners – Requirements for wood density*

BS EN ISO 10683 *Fasteners – Non-electrolytically applied flake coatings*

Summary of key points

- Metal fasteners have negligible fire resistance and absorb and transfer heat quickly. Fire protection with plasterboard is the most common solution.
- There are two main types of metal connectors: metal plate fasteners and connectors with bolts.
- Metal plate fasteners can be divided into two categories: two-dimensional plates (such as punched metal plates or nail plates, used to join two or more pieces of timber of the same thickness, in the same plane); and three-dimensional nail plates (such as joist hangers, framing anchors, truss clips and wall ties).
- There are two main types of two-dimensional (2D) plates: two-dimensional (2D) nail plates and two-dimensional (2D) punched metal plates.
- Eurocode 5 mentions three types of bolted connectors with their design methods: split-ring connectors, shear-plate connectors and toothed-plate connectors.

References

1. Ross, P., Hislop, P., Mansfield-Williams, H. and Young, A., *Concise illustrated guide to timber connections*, 1st edition, ISBN 978-1900510851, TRADA Technology, 2012

2. *Wood Information Sheet 2/3-52: Fasteners for structural timber: nails, staples, screws, dowels and bolts*, Exova BM TRADA, 2016

3. BS EN 1995-1-2004+A1:2008 *Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings*, BSI

4. NA to BS EN 1995-1-1:2004+A1:2008 *UK National Annex to Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings*, BSI

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