TRADA
wood information

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SECTION 2/3 SHEET 53
1996

Connectors and metal plate fasteners for structural timber

Timber connectors improve the transfer of loads by increasing the bearing area between the fasteners and the timber. They are of two broad types - those which use bolts to draw the members together and metal plate types which allow members to remain in the same plane. Metal plate fasteners rely on a number of nails, or other dowel-type fasteners, or upon integral teeth.

This Wood Information Sheet deals with timber connectors. The suitability of the various types is summarised in Table 1. Separate sheets cover *Timber engineering hardware*, for example joist hangers, truss clips, column shoes etc, and *Dowel-type fasteners for structural timber* (nails, screws, dowels and bolts).

TABLE 1 Connectors for structural timber

Type of connector	Loading		Easily demountable	Suitable for use in:			
	Lateral	Axial		Solid timber, glulam etc; density*		Plywood, chipboard, OSB	Steel to timber
				< 500 kg/m³	≥ 500 kg/m³		
Ring connectors	✓	☆	✓	✓	✓	≥ 22 mm thick	
Shear plate connectors	✓	☆	✓	✓	✓	≥ 40 mm thick	Single sided
Toothed plate connectors	✓	☆		✓		≥ 16 mm thick	Single sided
Metal plate connectors	✓	Some types		✓		Some types	

* Characteristic density at 20° C; 65% relative humidity. Less than 500 kg/m³ corresponds to softwoods in strength classes C14 - C40.
☆ Primarily intended for lateral loading, but the bolt can take axial loading if this occurs

CONNECTORS USED WITH BOLTS

Three types of bolted connector, specified in *BS 1579: 1960 Connectors for timber*, are included in BS 5268 Part 2. These are split ring connectors, shear plate connectors and toothed plate connectors. They will be covered in *EN 912 Timber fasteners - Specifications for connectors for timber.*

BS 1579 is still in imperial units but BS 5268 Part 2 and manufacturers' leaflets refer to dimensions exclusively in millimetres, although these are only slightly rationalised imperial sizes, such as 64 mm (2½ in.) and 102 mm (4 in.) for the split rings. Recommendations for suitable ISO metric bolts for use with connectors are available in BS 5268.

BS 5268 Part 2 includes rules for the design of joints using bolted timber connectors, together with guidance on appropriate edge and end distances (see WI Sheet *Dowel-type fasteners for structural timber* for explanation). Assessment of the effective cross-sectional area to take account of the timber section removed for the bolts and connectors is also important and this is explained in BS 5268 Part 2.

The ENV version of Eurocode 5, published in 1994 does not provide design procedures for timber connectors. Characteristic load carrying capacities will eventually be included in a European Standard, but this is not expected before 1998. In the meantime, a TRADA Interim Technical Data Sheet *Design data for timber connectors for use with Eurocode 5* provides guidance.

RING AND SHEAR PLATE CONNECTORS

In prEN 912 ring connectors (known as split rings in BS 1579) are designated as Type A. Shear plates are Type B. Ring connector units (Figure 1) consist of one split-ring with bolt, washers and nut. The dimensions of the ring, bolt and washers comply with the values given in the standards and the ring itself may be of parallel or bevel-sided form. The bevel-sided form is claimed to be easier to insert and to give greater load capacity, although BS 5268 Part 2 does not distinguish between the two in recommending basic loads.

Rings and shear plates are formed from steel, aluminium cast alloy or cast iron. Diameters vary from 60 to 260 mm. They are circular and are placed in pre-cut grooves produced by rotary cutters.

Ring and shear-plate connectors are used in laterally loaded timber-to-timber and steel-to-timber joints. Ring connectors are exclusively applied in timber-to-timber joints, whilst shear-plate connectors may be used for steel-to-timber as well. Shear-plate connectors are normally installed before the assembly of the structure, although the joints are demountable.

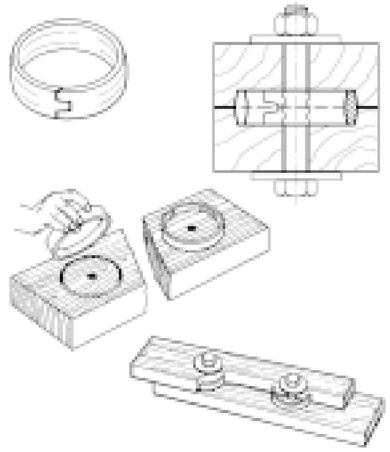

Figure 1 Ring connectors

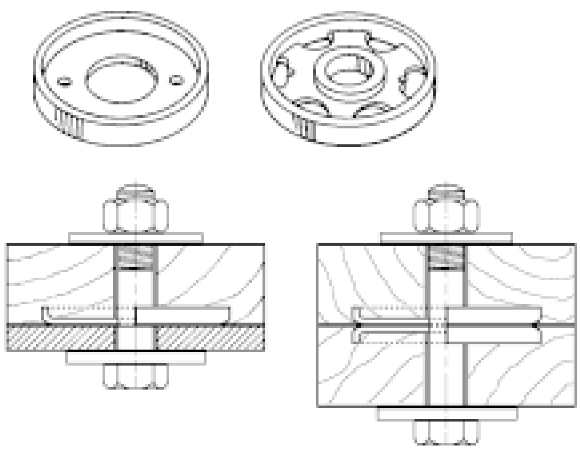

Figure 2 Shear plate connectors (top left pressed steel type, top right malleable cast iron type)

The fabrication of ring and shear-plate connector joints comprises several steps. First, the bolt hole and the connector groove are drilled into the wood. The cutters used to make the grooves should correspond to the shape of the ring cross-section. Then the connectors are placed into the grooves and the timber members to be connected are put together. Finally, the bolts are inserted into the holes and tightened. Alternatively, coach screws may be used to hold the connection together.

Load Carrying Behaviour

Precision in grooving and boring is essential for the correct installation and satisfactory performance of these types of connector.

The load in a ring connector joint is transferred from one timber member to another through embedding stresses via the ring connector. The connected member must also offer adequate shear resistance. In shear-plate connections, the load transfer is slightly different: after the transfer of the load into the connector, the bolt is loaded through bearing stresses between the shear-plate and the bolt, and the load is transferred through the shear resistance of the bolt. Then, the second shear-plate or a steel member is loaded by the bolt. In shear-plate connections the hole diameter in the shear-plate consequently corresponds to the bolt diameter plus a small tolerance. Due to this tolerance, a greater initial slip can be expected in shear-plate connections.

TOOTHED-PLATE CONNECTORS

Toothed-plate connectors are made from cold rolled band steel or hot dipped galvanised mild steel. They are available in a variety of shapes and sizes, with diameters ranging from 38 to 165 mm. Larger connectors are available for use in glued-laminated members. They are mostly circular, but square and oval shapes are also available. Toothed-plate connectors are denoted as Type C in prEN 912 and are also specified in BS 1579. The joints are normally held together by bolts installed with round or square washers of a size about half the diameter of the connectors used.

Like ring or shear-plate connectors, toothed-plate connectors are used in laterally loaded timber-to-timber and steel-to-timber joints. They are pressed into the timber members to be connected. Double-sided toothed-plate connectors are used in timber-to-timber joints; alternatively, pairs of single-sided connectors may be used back-to-back if the joints should be demountable. Single-sided connectors are also used in steel-to-timber joints. Since the teeth are pressed into the timber, toothed-plate connectors can only be used in timber or wood-based panel products with a characteristic density of not more than about 500 kg/m^3.

Toothed-plate connector joints are manufactured in a similar way to bolted joints. First, the bolt hole is drilled in the wood, then the connectors are placed between the timber members and the connection is pressed together. Pressing the connector teeth into the timber requires considerable force and either a hydraulic press or a high strength bolt is used. Only for small connector diameters, up to 65 mm, can the permanently installed mild steel bolt be used. If bolts are used to press the connector teeth into the wood, large washers are required because of the otherwise high stresses perpendicular to the grain and the consequent crushing of the wood. After pressing, the high strength bolt is replaced by the permanent mild steel bolt using washers normal for timber structures (see WI Sheet *Dowel-type fasteners for structural timber*). The joint should obey all the normal design rules for bolted joints. Coach screws may also be used in connection with toothed-plates, as an alternative to bolts.

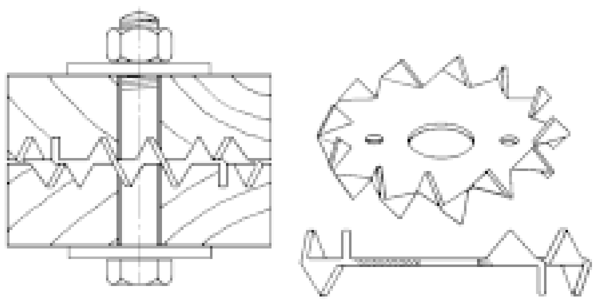

Figure 3 Double-sided toothed plate connectors

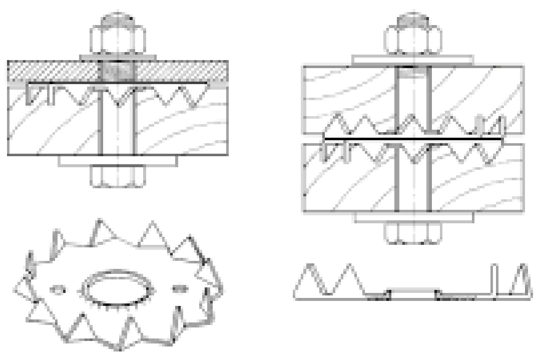

Figure 4 Single-sided toothed plate connector

Load Carrying Behaviour

The load in a double-sided toothed-plate connector joint is transferred from one timber member to the other through embedding stresses, into the teeth of the connector and further through the plate, into the teeth on the opposite side. In single-sided toothed-plate connections, the load transfer is slightly different: after the transfer of the load into the connector, the bolt is loaded through embedding stresses between connector and bolt and the load is transferred by shear in the bolt. Then, either the steel member, or the second toothed-plate is loaded by the bolt. In single-sided connections, the hole diameter in the toothed-plate consequently corresponds to the bolt diameter plus a small tolerance. Due to this tolerance, a larger initial slip can be expected in single-sided connections.

Summary: Rings and shear plates

- Ring connector joints are used in laterally loaded timber-to-timber connections, whilst shear-plate connector joints can also be applied in steel-to-timber connections.
- Timber and connector dimensions, spacing, end distances and density are the primary influences on the connection strength. These are stipulated in design codes.
- Connection stiffness depends mainly on the connector diameter and the timber density.

Summary: Toothed plates

- Double-sided toothed-plate connector joints are used in laterally loaded timber-to-timber connections, whilst single-sided toothed-plate connector joints can be used in steel-to-timber connections and in demountable timber-to-timber joints.
- Connector and timber dimensions, as well as the load-carrying capacity of the bolt are the primary influences on the connection strength.
- Connection stiffness depends mainly on connector diameter and the timber density.
- Toothed-plate connector joints cannot easily be used for timbers with a characteristic density of more than about 500 kg/m^3.

Split-rings and double-sided toothed-plates are used in a similar way to one another for timber joints. They transfer the load directly between the surfaces of the members that are in contact. Final assembly is generally done on site. On the other hand, shear-plates and single sided toothed-plates are suitable for steel-to-timber joints as well as for timber-to-timber joints. They allow the prefabrication of the joints and only the bolts are installed on site. For these connectors, the load transfer is achieved by the bolt which is stressed in shear by bearing contact with the connector plates.

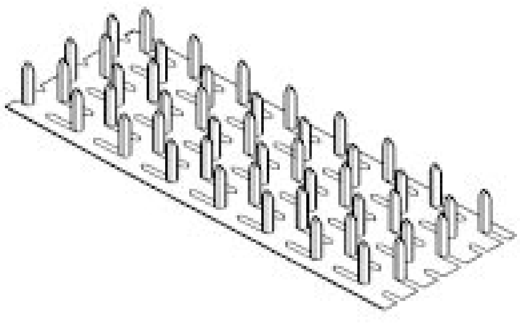

Figure 4 Punched plate metal fastener

METAL PLATE FASTENERS

PUNCHED METAL PLATES

A 'punched metal plate' is defined in prEN 1075 as a fastener made of metal plate, having integral projections punched out in one direction and bent perpendicular to the base of the plate, being used to join two or more pieces of timber of the same thickness, in the same plane. They are generally manufactured from pre-galvanised mild steel strip or stainless steel strips, with thicknesses ranging from 0.9 to 2.5 mm.

Punched metal plate fasteners 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 light-framed timber trussed rafters and also for in-plane joints in other components. Care should be taken in handling such components since the joints are flexible out-of plane and can be damaged during erection. Guidance on handling is contained in BS 5268 Part 3 and in prEN 1059.

Different forms of proprietary punched metal plates have been developed, involving a variety of nailing patterns, nail lengths and nail shapes. Strength is dictated by certain key influencing variables. A common design approach is being established in EC5 and design procedures are well defined in BS 5268 Part 3 and accompanying documents.

Computer Aided Design

Most design of punched metal plate joints is undertaken by specialist fabrication companies, using purpose written CAD packages.

Load carrying behaviour

Load is transferred in a punched metal plate fastener 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. Joints are designed and fabricated with pairs of plates on opposite faces of the member.

BS 5268 Part 3 gives positioning rules and rules for load capacity for punched metal plates. Permissible loads for use with the Code were determined by testing and are given in Technical Approvals.

EC5 includes a number of formulae which predict the strength of joints based on certain key characteristic plate strength properties. These plate properties should be established from standard tests whose basis is given in prEN 1075. In addition to calculation rules, EC5 includes certain ad-hoc rules for dimensioning punched metal plate fasteners.

Joint slip may be allowed for in truss deflection calculations either by the use of slips prescribed in Codes or by slip moduli established from joint tests in accordance with EN 26891.

NAIL PLATES

Nail plates are usually manufactured from galvanized mild steel capable of receiving hand-placed nails. A typical thickness is 1 mm, with pre-formed holes for nails (Figure 5). Manufacturers recommend the use of improved nails, eg square twisted types. The nails should be a tight driving fit in the plate holes.

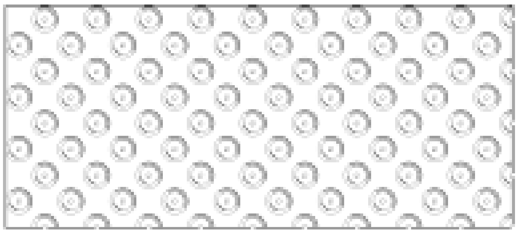

Figure 5 Nail plate

FIRE RESISTANCE

The calculation methods for the performance of timber in fire given in BS 5268 Part 4 Section 4.1 apply only to timber members where the fasteners are fully protected from the effects of fire. All-round protection with timber or wood based materials offers insulation from heat, thereby protecting the steel members. Joints are considered protected if the fasteners are covered with adequate protective plugs of timber or wood-based panels. EC5 Part 1-2 gives a series of calculation methods of varying complexity for the fire resistance of timber members and timber components, with the basic method being similar to that contained in BS 5268 Part 4.

The classification of timber members into fire resistance classes requires that not only the single components they are built from, but also the connections, should satisfy the requirements for fire resistance.

REFERENCES

British and European Standards

BS 5268 The structural use of timber
Part 2: 1991 Permissible stress design, materials and workmanship. (Revised edition due 1996).
Part 3: 1985 Code of practice for trussed rafter roofs.

DD ENV 1995-1-1: 1994 Eurocode 5: Design of timber structures. Part 1.1 General rules and rules for buildings.

prEN 912 Timber fasteners - Specifications for connectors for timber.

prEN 1059 Timber structures. Production requirements for fabricated trusses using punched metal plate fasteners.

prEN 1075 Timber structures. Test methods. Joints made of punched metal plate fasteners.

BS EN 26891: 1991 Timber structures. Joints made with mechanical fasteners. General principles for the determination of strength and deformation characteristics.

TRADA PUBLICATIONS

Wood Information Sheets

WIS 1 - 37 Eurocode 5 - An introduction. 1995
WIS 2/3 - 36 Structural timber joint design to Eurocode 5. 1995
WIS 2/3 - 51 Timber engineering hardware. 1995
WIS 2/3 - 52 Dowel-type fasteners for structural timber. 1995
WIS 4 - 20 Structural softwoods - Key British and European Standards. 1995
WIS 4 - 21 European strength classes and strength grading
WIS 4 - 24 Serviceability limit states for timber in buildings. 1995

Eurocode 5 Guidance

A binder containing a set of guidance material is available for purchase from TTL. Individual documents are also available; those most relevant are listed below.

EC5 Guidance Documents
GD 2 How to calculate design values for loads. 1994
GD 3 How to calculate the design values of material properties. 1994
GD 4 How to calculate deformations. 1994

EC5 Interim Technical Data Sheets
ITD 3 Design data for timber connectors for use with Eurocode 5. 1994

EC5 Design examples
Introduction to design examples. 1994
Joints. 1994

EC5 Design Aids
EDA 2 Fastener load tables. 1994

STEP publications

These are sold in the UK through TRADA Technology Ltd

Timber Engineering STEP 1. Centrum Hout, Almere. 1995.
Timber Engineering Step 2. Centrum Hout, Almere. 1995.

This Wood Information Sheet was prepared by TRADA Technology Ltd (TTL) for TRADA. TTL provides extensive testing and consultancy services as well as providing member services for TRADA.

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