WOODINFORMATION

Fasteners for structural timber: nails, screws, bolts and dowels

The traditional mechanical fasteners for structural timber are divided into two groups depending on how they transfer the forces between the connected members.

The first group, covered by this Wood Information Sheet, corresponds to the dowel-type fasteners: nails, bolts, dowels and screws. Here, the load transfer involves both the bending behaviour of the dowel and the bearing stresses in the timber along the shank of the dowel.

The second type includes fasteners such as split rings, shear-plates, and punched metal plate fasteners in which the load transmission is primarily achieved by a large bearing area at the surface of the members. This group is covered in a companion Wood Information Sheet, *Connectors for structural timber*.

Nails

Nails are the most commonly used fasteners for many forms of structural timber component, such as timber frame stud walls and floor diaphragms. In timber structures, nails are used primarily in single shear for connecting timber, steel or wood-based panel products together.

Nails are manufactured in many different sizes, shapes and materials, but the most common is the round wire nail. Some manufacturers also produce a square cross-sectional nail, used in similar applications. The round wire nail is cut from a steel wire coil that has a circular cross sectional area, and a minimum tensile strength of 600 N/mm^2, and is available in a standard range of diameters, from 2.65 mm to 8 mm. The head is forged into a flat circle of a diameter approximately twice that of the shank. Some nails have smaller heads which can be driven flush with the timber surface. If these are specified in structural design, particularly in applications involving wood-based panel products, care should be taken to ensure that there is no risk of head pull-through.

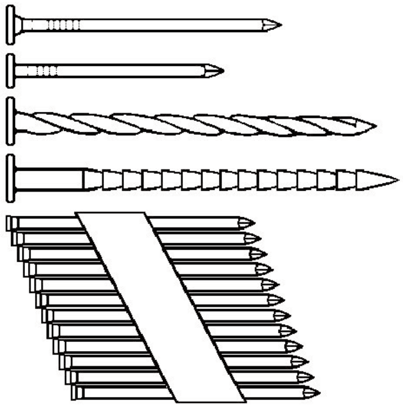


Figure 1 Types of nails
from top: Round wire, twisted shank, annular ringed shank, cartridge for pneumatic fixing

Pre-drilling holes for larger nails may be necessary when driving into dense hardwoods, or into softwoods such as larch and Douglas fir, to avoid splitting. The hole diameter should not be more than 80% of the nail diameter.

Nail performance, both under lateral and withdrawal loading, may be improved by modifying the surface of a smooth round nail. A common choice is to use annular ringed or helically threaded shank nails. These are produced by cutting annular or helical threads on to the shank of the nail to provide greater withdrawal strength. Another variation is to take nails with a square cross section and twist them into a helical pattern, not only modifying the surface but also work hardening the steel, thus raising the yield strength. These improvements are mainly in terms of withdrawal resistance of the nail, although they may also indirectly improve the lateral strength.

Chemical etching, galvanising and other suitable forms of coating are ways in which the corrosion-resistance of nails may be enhanced. Such coatings may also have a small improving effect on the load carrying capacity of the nail. Information on this is not normally given in codes but is product-specific.

Proprietary nails with a segment of the head cut away and T-nails are also available, in lengths up to approximately 100 mm, for use in pneumatic tools. Their head design allows them to be assembled into cartridges. They are usually made of steel which is somewhat stronger than that used for common round wire nails.

The most common types of nail are covered in BS EN 10230-1 but special nails, including improved nails, are still covered by BS 1202-1.

Wood screws

Wood screws can be used for plain timber-to-timber joints but are especially suitable for steel-to-timber and panel-to-timber joints. Such screwed joints are usually designed as single shear joints. Screws should be inserted by turning and not by driving with a hammer, otherwise the load-carrying capacity will decrease significantly.

A European standard has not yet been produced for screws. The design rules given in BS 5268-2 apply to screws to BS 1210. The diameter relates to the smooth shank, which ranges from 6 mm to 20 mm for coach screws, and from 4 mm to 8 mm for countersunk and round head screws. Screws with a diameter greater than 5 mm should be turned into predrilled holes to prevent splitting of the wood. The root diameter of most screws in the threaded portion is about 70% of the diameter measured on the smooth shank. The depth of the thread varies from 0.125d to 0.140d and the thread pitch from 0.4d to 0.5d. The length of the threaded portion is normally about 60% of the total length of the shank.

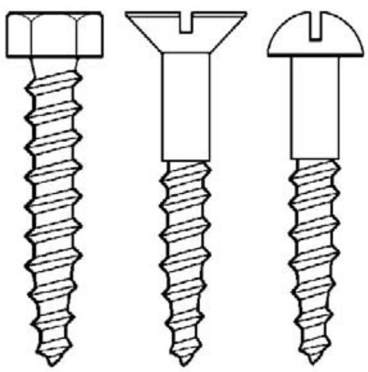


Figure 2 Wood screws
(left) Coach screw, (centre) Countersunk head, (right) Round head

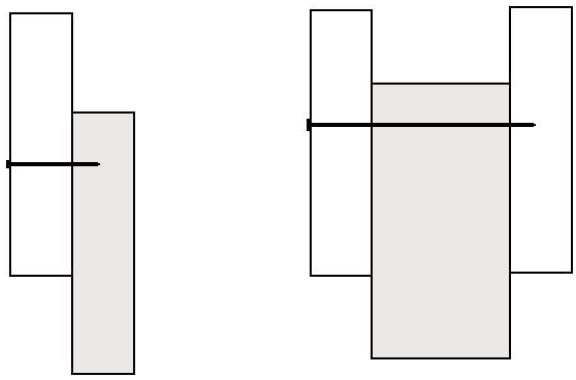


Figure 3 Shear joints
(left) Single (right) Double

The main type of screw used in engineered timber structures is the coach screw, with a nut-like head. It requires a washer and must always be inserted into a pre-drilled hole. Coach screws can be found in lengths of 25 mm to 300 mm and are generally produced in accordance with the German Standard DIN 571. In large connections, they conveniently hold timber connectors in place or replace bolts for single-sided access. Another use is to fix joist hangers or framing anchors.

Bolts and dowels

Bolts and dowels are used to hold two or more members together to form a joint, generally loaded in shear. They are usually made from mild steel with a minimum tensile strength of 400 N/mm^2.

Bolts are threaded dowel type fasteners, with hexagonal or square heads and nuts. They are available in diameters from 8 mm to 30 mm. When installing a bolt, the pre-drilled hole must include a clearance to allow for easy insertion of the bolt. This also reduces any tendency for the members to split on assembly or after drying out. BS 5268-2 allows a diameter up to 2 mm larger than the bolt diameter, but Eurocode 5 allows a maximum difference of 1 mm. Bolts should be tightened so that the members fit closely and should be retightened when the timber members reach equilibrium moisture content.

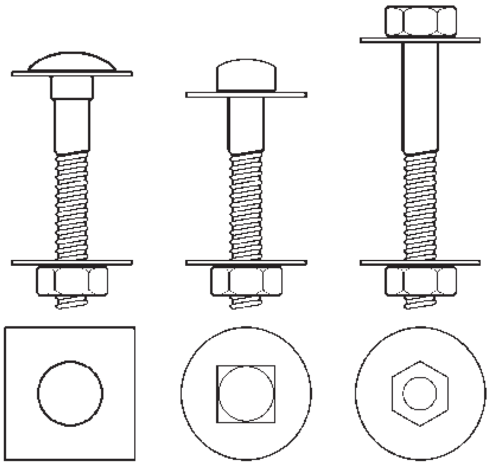


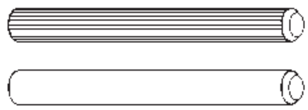
Figure 4 Bolts
(left) Carriage bolt, (centre) Square head, (right) hexagonal head

Whenever a bolt is used, either on its own or through a connector, it should be installed with a washer under any heads or nuts which are in contact with the timber. Timberwork washers should have a diameter of a least 3 times the diameter of the bolt and a thickness of 0.3 bolt diameters to provide an adequate bearing area. Bolt heads and nuts in contact with steel surfaces follow normal washer rules for metalwork.

Dowels are cylindrical rods, generally of smooth surface, available in diameters typically from 6 mm to 30 mm. They are inserted into predrilled holes with a diameter not greater than that of the dowel itself. This means that the holes must be accurately positioned, which is generally achieved by drilling through one member into the other. Joints made with dowels have a better appearance than bolted joints and are also stiffer. If steel members are incorporated in a dowelled joint, the holes in the steel members must include a clearance, and due allowance should be made for any extra slip that may occur as a result. Timber engineered connections are possible in which dowel heads are welded to steel plates.

In large dowelled connections it may be necessary to replace some of the dowels with threaded bolts in order to stop the joint from opening laterally. Bolted and dowelled joints may be made stronger by incorporating a resin into the joint. The technique is mentioned in the TRADA Wood Information Sheet *Resin-bonded repair systems for structural timber*.

Figure 5 Dowels



Design

The design of joints using dowel-type fasteners should be undertaken in accordance with BS 5268-2 or Eurocode 5 (EC5). Although it remains a permissible stress design code, BS 5268-2 now takes the EC5 approach to the design of nailed, screwed, bolted and dowelled joints.

This section outlines the principles of joint design using dowel-type fasteners in timber. More detailed information can be obtained from the codes themselves, from guidance contained in TRADA Publications, particularly the Eurocode 5 Design Guidance documents, the WIS *Structural timber joint design to Eurocode 5* and from the STEP publications (see References). The terminology and notation used here is largely based on Eurocode 5, but the principles in all the above publications are very similar.

Spacing rules

Dowel-type fasteners must be spaced at suitable distances from each other and from the ends and edges of timber or wood-based materials. This is to avoid splitting. The various distances involved are shown in Figure 6.

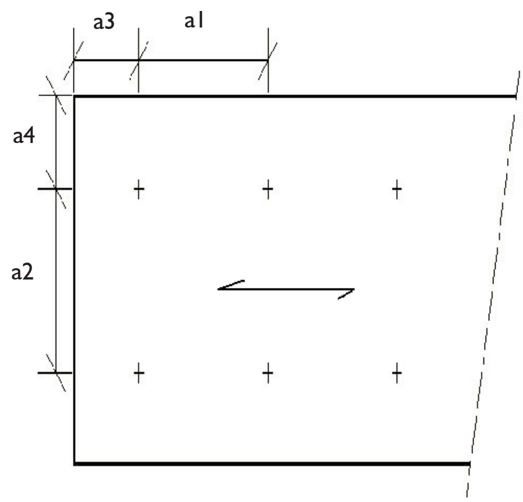


Figure 6 Spacing rules
a1 Spacing parallel to grain
a2 Spacing perpendicular to grain
a3 End distance (may be loaded or unloaded)
a4 Edge distance (may be loaded or unloaded)

An end distance is said to be loaded when the load on the fastener has a component towards the end of the timber. Otherwise, it is referred to as an unloaded end distance. Loaded end distances need to be greater than unloaded ones. In a similar way, the edge distance may be loaded or unloaded.

The values for spacings and distances vary from one fastener type to another, as well as between the various material types. Factors taken into account in producing the code recommendations include the cleavage and shear strength of the timber, the timber density, the fastener diameter and, in some cases, the angle of load to the grain. The spacings and distances recommended in the codes are based upon testing and years of experience. Deviations should not be made unless strongly supported by tests and by an independent authority.

Design basis

Lateral loading

In most joints made with nails, screws, bolts or dowels, the fastener is loaded in lateral shear. To calculate the load-carrying capacity of such a joint, three material properties are needed. These are the timber density, the embedment strength of the timber or wood-based material and the bending strength of the fastener.

EC5 provides formulae, based on test results, for calculating the characteristic embedment strength of commonly used fastener/timber combinations from the density of the timber and the diameter of the fastener. Similar formulae are included in an Appendix to BS 5268-2. In the case of EC5, the characteristic embedment strength is converted to a design value by applying the appropriate load duration factor and the partial safety factors for timber and connectors. The tables of basic loads for fasteners in BS 5268-2: 2002 have been derived using the same principles as EC5, but with load-carrying capacities adjusted to match the permissible stress design basis of this code. Design rules are given in Section 6 of BS 5268-2 by means of which permissible loads are developed.

The characteristic bending strength of the fastener is calculated from formulae given in EC5 and converted to a design value by applying a partial safety factor for the fastener material. In the BS 5268-2: 2002 tables, fastener strengths are similarly taken into account. For non-standard and proprietary types of fastener or wood-based material, test methods for determining the embedding strength of the fasteners and the yield strength of dowels are taken from EN standards.

For laterally loaded joints, there are numerous possible modes of failure of the joint. This is explained in more detail in the Wood Information Sheet *Structural timber joint design to Eurocode 5*. To avoid the need for repetitive calculations, TRADA in its EC5 Design Guidance has produced a Design Aid (EDA 2) giving tables of pre-calculated design values for a range of joint types. The tables can be used in a similar way to the tables of basic fastener loads which are given in BS 5268-2: 2002 but include some additional materials: hardboard for nailed joints, softwood glulam and one type of LVL for bolted and dowelled joints. They also show the failure modes, enabling the designer to identify quickly the weakest element in a joint.

There are currently no tables for screws with a shank diameter larger than 10 mm, but the strength of joints made with larger coach screws can be calculated using Annex G of BS 5268- 2 or EC 5, provided that the strength of the steel from which they are made is known.

Axial loading

EC5 and BS 5268-2 give a design method for nails and screws loaded in axial withdrawal. The method in EC5 is in some ways more comprehensive, in that it covers head pull-through in the case of nails with small heads and includes a design method for slant nailing. BS 5268-2 on the other hand, includes some useful guidance on withdrawal loads for improved nails, which is not fully covered by EC5.

Slip

Slip between the component parts occurs to some degree in all mechanical joints as the joint takes up load. It can be a significant factor in the deformation and, in some cases, the strength of some components. BS 5268-2 and EC5 both include calculation methods for slip in joints. The magnitude of slip is time-dependent and is also affected by fluctuating moisture content in the timber. Further information is included in the Wood Information Sheet *Serviceability limit states for timber in buildings*.

Fire resistance

The loadbearing capacity of unprotected metal fasteners in a fire is considerably reduced by heat. Where any part of a nail, screw, dowel or bolt is exposed to fire, rapid heat conduction will also lead to localized charring of the wood around the fastener, resulting in loss of anchorage. A calculation method is given in BS 5268-4 Section 4.1 to ensure that fasteners are fully protected from the effects of fire.

Joints are considered protected if the fasteners are covered with protective plugs of wood or wood-based panels. EC5-1.2 gives a series of calculation methods of increasing complexity for the fire resistance of timber members and timber components, with the basic method similar to that contained in BS 5268-4.

Comparative performance

Figure 7 indicates the relative load-carrying capacity per shear plane per fastener for a timber to timber joint loaded parallel to the grain in single shear. This is based upon EC5 design principles but the relativity between the various fasteners would be similar in a design based on BS 5268-2. A typical softwood strength class, C24 (to which SS grade European redwood and whitewood belong), was used for the comparison and a medium term load duration class was assumed. Timber member thicknesses typically used with the various fasteners were assumed.

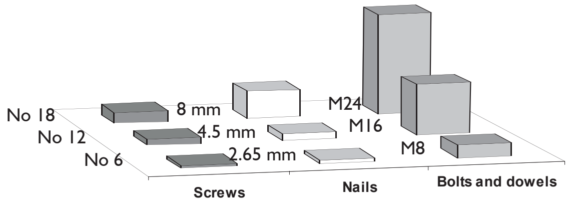


Figure 7 Typical design load-carrying capacity per fastener for a timber-to-timber, parallel to grain, single shear joint

Clearly large bolts and dowels are much heavier duty fastening devices than nails or screws and therefore have the greatest load carrying capacity of the types shown in this WIS.

When comparing nails and screws of a similar diameter it can be seen that nails generally have an advantage in terms of lateral load-carrying capacity. Screws are normally chosen rather than nails for other reasons, such as demountability. They also have better axial withdrawal resistance, which is not covered in the diagram.

References

Standards

BS 5268-2: 2002 The structural use of timber. Permissible stress design, materials and workmanship.

BS 5268-4 Section 4.1: 1978 The structural use of timber. Fire resistance of timber members. Recommendations for calculating the fire resistance of timber members.

BS 5268-4 Section 4.2: 1990 The structural use of timber. Fire resistance of timber members. Recommendations for calculating the fire resistance of timber stud walls and joisted floor constructions.

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

DD ENV: 1995-1-2: 2000 Eurocode 5: Design of timber structures. General rules. Structural fire design.

BS 1202-1: 2002 Specification for nails Part 1: Steel nails.

BS 1210:1963 Specification for wood screws (Obsolescent).

BS EN 383: 1993 Timber structures. Test methods. Determination of embedding strength and foundation values for dowel type fasteners.

BS EN 409: 1993 Timber structures. Test methods. Determination of the yield moment of dowel type fasteners. Nails .

BS EN 10230-1: 2000 Steel wire nails. Loose nails for general applications.

DIN 571: 1986 Hexagon head wood screws

TRADA Publications

Wood Information Sheets

WIS 1 - 37 Eurocode 5 - An introduction.

WIS 2/3 - 36 Structural timber joint design to Eurocode 5.

WIS 4 - 21 European strength classes and strength grading.

WIS 4 - 24 Serviceability limit states for timber in buildings.

WIS 2/3 - 53 Connectors and metal plate fasteners for structural timber.

EC5 Guidance Documents

GD2 How to calculate design values for loads. 1994.

GD3 How to calculate the design values of material properties. 1994.

GD4 How to calculate deformations. 1994.

EC5 Design examples

Introduction to design examples 1994

J1 - 4 Joints 1994.

(Calculations for nailed single lap tension joint, bolted double lap tension joint, screwed single lap joint with members at 90° dowelled double lap joint with members at 45°)

J5 - 8 Multiple fastener joints to BS 5268-2 and Eurocode 5. 1999.

(Calculations for nailed ply-gusseted tension joint for a roof truss to BS 5268-2, dowelled steel flitch plate tension joint in bottom chord of girder truss to EC5, dowelled steel plate beam-to-column connection to EC5, bolted timber-to-timber connection to BS 5268-2)

P1 Swimming pool. 1998.

(Calculations for an LVL 3-pinned frame with steel dowelled or bolted joints)

EC5 Design Aids

EDA 2 Fastener load tables. Revised 1998.

STEP publications

These are sold in the UK through TRADA Technology Ltd

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

(Chapters C1 - C8 and C14 - C19 are especially relevant)

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

TRADA Technology Ltd

Stocking Lane, Hughenden Valley, High Wycombe, Buckinghamshire HP14 4ND, UK

Tel: +44 (0)1494 569600 Fax: +44 (0)1494 565487 email: information@trada.co.uk

www.trada.co.uk