

Methods of test for

Mechanically fastened joints in timber and wood-based materials

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The preparation of this British Standard was entrusted by the Timber Standards Policy Committee (TIB/-) to Technical Committee TIB/5, upon which the following bodies were represented:

- Association of Building Component Manufacturers Ltd.
- British Plastics Federation
- British Woodworking Federation
- Building Employers Confederation
- Department of the Environment
- Department of the Environment (Building Research Establishment, Princes Risborough Laboratory)
- Department of the Environment (Housing and Construction)
- Fibre Building Board Development Organization Ltd.
- Forestry Commission
- Institute of Wood Science
- Institution of Civil Engineers
- Institution of Municipal Engineers
- Institution of Structural Engineers
- National Sawmilling Association
- Royal Institute of British Architects
- Royal Institution of Chartered Surveyors
- Timber Packaging and Pallet Confederation
- Timber Research and Development Association
- Timber Trade Federation

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- Agrement Board
- Greater London Council
- The Transmission and Distribution Association (BEAMA)

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Foreword

This British Standard has been prepared under the direction of the Timber Standards Policy Committee.

In formulating this British Standard, account has been taken of RILEM Recommendation TT-1 “*Testing methods for joints with mechanical fasteners in load-bearing timber structures*”, published by the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), and ISO 6891 “*Timber structures — Joints made with mechanical fasteners — General principles for the determination of strength and deformation characteristics*”, published by the International Organization for Standardization.

Although the test methods given in this British Standard have been formulated from experience gained with fasteners made from steel, they may also be used for fasteners made of other materials. For convenience mechanical fasteners have been classified into categories and test methods have been defined for the determination, as appropriate, of their withdrawal strength, pull-through strength, and lateral strength and stiffness in joints of timber and wood-based materials. Further sections for additional categories will be issued as required.

Some species of timber may have special nailing or splitting characteristics requiring separate investigation and this should be borne in mind when preparing test programmes.

The test data obtained will not be suitable for design purposes without appropriate evaluation. Design data for established fasteners are included in BS 5268.

No information on precision has been given in this British Standard but the matter is under consideration.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 34, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General requirements

0 Introduction

The strength properties of mechanically fastened joints depend on the materials that are jointed; the type, size and number of fasteners; the thickness, width and configuration of the members within the joints; and on the direction of loading and exposure conditions to which the joints are subject in service. So many factors are involved that for the design of joints an approach has been developed which is based on the determination of basic strength values for a particular fastener, and modification factors so that these can be adjusted to obtain strength values for any particular joint. For this approach to be effective it is necessary for the strength of the fasteners to be determined under standard conditions.

It is recognized that occasions will arise when it will be necessary to establish the suitability of a particular joint design from tests on prototype units. Although this is not dealt with specifically in the standard, account should nevertheless be taken of its general recommendations when designing a test programme. Even for testing within the scope of the standard it is desirable to formulate a suitable test programme at the outset, to ensure that the required information is obtained. This will often require consideration to be given to the range of sizes of fasteners available, and to the many different types of joint that can be produced.

For the determination of design loads, consideration should also be given to questions of material sampling, number of tests, variability and data analysis. These questions are beyond the scope of this standard and indeed can only be answered in relation to particular fasteners, materials, joints and loading conditions.

1 Scope

This standard describes methods of test for the determination of the strength and stiffness of mechanical fasteners when used to make joints in timber and/or wood-based materials.

The test procedures cover the withdrawal strength, pull-through strength and lateral strength of joints and the tension strength and shear strength of punched metal fasteners. With appropriate modification of the test specimens, the tests may be used to establish the effects on joint strength of various factors related to the design of joints such as end and edge distances, number and spacing of fasteners, thickness of members, depth of penetration, moisture content, etc.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions and graphical symbols

2.1 Definitions

For the purposes of this British Standard the definitions given in BS 6100 apply, together with the following.

2.1.1

fastener

integral or composite mechanical device for joining or supporting overlapping or abutting members of timber or wood-based material thus forming a mechanically fastened joint

2.1.2

lateral loading

transverse loading on a fastener (or teeth of category C and D fasteners) caused by forces acting in the planes of the jointed members

2.1.3

pull-through loading

loading on a fastener caused by forces acting to pull the head (or non-embedded parts) of the fastener through a member

2.1.4

withdrawal loading

loading on a fastener caused by forces acting to pull the fastener out of a member

2.1.5

specimen

joint that is shaped and assembled in accordance with this standard

2.1.6

diameter of fastener (*d*)

diameter used to determine sizes of members and fastener spacings that shall be the nominal value used for specifying the fastener

2.2 Graphical symbols

⊥	Perpendicular (to the grain)
∥	Parallel (to the grain)
↔	Grain direction

3 Testing machines

All strength tests shall be made using a testing machine that complies with the requirements for grade 0.5 machines of BS 1610-2:1989. The rate of cross-head movement and the rate of loading shall be capable of control to within $\pm 25\%$ of the rate specified for a particular test.

4 Test programme

4.1 General

A test programme shall be drawn up giving details of the objectives, the type of fastener, the specimen assembly and the number of specimens to be tested. The programme shall include a schedule of tests, a description of the fasteners and a description of the specimen to be used.

4.2 Schedule of tests

The schedule of tests shall set out the type of tests, the size and number of fasteners to be tested.

4.3 Description of fasteners

The category (see Table 1), type, dimensions and specification of materials and finishes shall be included in the test programme.

The categories of fasteners are as set out in Table 1.

Table 1 — Categories of fasteners

Category	Type of fastener
A	Nails, staples, screws and similar fasteners
B	Bolts, dowels, connector units and similar fasteners
C	Metal plates with integral teeth and similar fasteners
D	Perforated metal plates fastened by separate nails

4.4 Description of specimens

The description of specimens shall include the type and dimensions, species, grade, surface finishes, grain and growth ring orientation, etc. Selection and cutting schedule of members, number of fasteners, and assembly of specimens shall also be included in the test programme.

5 Selection of materials

5.1 Fasteners

Fasteners shall be selected as far as possible to be representative of normal production stock. This may require selecting them at random from a number of production batches, from different machines, and at different times.

5.2 Timber

Timber shall be selected at random from normal commercial parcels of the required species and grades. Those pieces that may be unsuitable because of defects shall be rejected.

In the areas where fasteners are to be placed the members shall be free from visible defects which might influence the test results. The members for a specimen shall all be cut from the same piece of timber. Each specimen in a set of similar specimens shall be made from a different piece of timber.

NOTE When the effect of a particular factor, for example moisture content or grain angle, is being determined, then it is preferable to obtain matched specimens for each level of the factor from each piece of timber.

5.3 Wood-based materials

Wood-based materials shall be selected at random from normal production stock of the required type and grade.

In the areas where fasteners are to be placed the members shall be free from all visible defects which might influence the test results. The members for a specimen shall all be cut from the same board. Not more than three specimens shall be made from the same board.

NOTE When the effect of a particular factor, for example moisture content, is being determined, then it is preferable to obtain matched specimens for each level of the factor from each board.

6 Test specimens

6.1 Number of specimens

Where the object of the test programme is to obtain basic strength data for a particular fastener, then not less than 15 specimens of a particular type shall be tested for lateral strength, and not less than 20 specimens of a particular type for withdrawal and pull-through strength.

In deciding on the number of specimens for other tests, account shall be taken of the anticipated variability and the required confidence level for the results.

6.2 Members

The members in a specimen shall be of the size, and have a surface finish, orientation of growth rings, direction of grain etc, as required by the test programme.

Generally timber members shall have a planed finish and members of wood-based materials shall have a finish as normally supplied commercially. For the determination of basic strength data the members shall have the dimensions specified in the test programme, after conditioning in accordance with this standard.

All dimensions shall have a tolerance of ± 0.5 mm or 1 %, whichever is the greater.

6.3 Assembly

Specimens shall be assembled in accordance with the requirements of the test programme and relevant test procedure, using the techniques normally adopted in production.

7 Conditioning before test

7.1 Conditioning of materials

Except when the effects of moisture content are being investigated the timber and wood-based materials shall be stored, before machining and assembly, in controlled air conditions of 20 ± 2 °C temperature and 80 ± 5 % relative humidity until equilibrium moisture content is attained.

NOTE 1 It can be expected that under these conditions the average moisture content will fall within the ranges of 17 % to 19 % for timber, 14 % and 16 % for plywood, and 10 % to 12 % for tempered hardboards.

NOTE 2 Where the material is already at a moisture content within these ranges the conditioning treatment may be omitted.

7.2 Conditioning of test specimens

Test specimens shall be stored in the controlled conditions for at least 12 h after assembly and prior to testing.

8 Conditions at test

The desirable ambient test conditions are 20 ± 2 °C and 65 ± 5 % relative humidity. If the actual conditions during testing are different attention shall be drawn to this fact in the test report.

Specimens shall not be exposed to the test conditions for longer than 1 h before testing. Specimens at the required equilibrium moisture content may be stored in the testing area for up to 24 h as long as they are close piled and wrapped in polyethylene sheeting.

9 Determination of moisture content and relative density after test

9.1 Sampling of test specimens

Immediately after test a small full cross-section sample of each member of a specimen shall be taken, close to the fastener. Each sample shall be defect free and at least 25 mm long.

9.2 Procedure

9.2.1 Measure the sample to the nearest 0.1 mm.

9.2.2 Weigh the sample to an accuracy of 0.05 g.

9.2.3 Dry the sample in an oven at a temperature of 103 ± 2 °C until the mass is constant.

NOTE A drying time of about 48 h will generally be sufficient to reach constant oven dry mass.

9.3 Expression of results

The moisture content (ω) of each test sample, expressed as a percentage by mass, is calculated from the equation:

$$\omega = \frac{M - M_0}{M} \times 100$$

where

M is the initial mass (in g);

M_0 is the oven-dry mass (in g).

The relative density (ρ) of each test sample shall be calculated from the equation:

$$\rho = \frac{M_0 10^3}{lbd}$$

where

l is the length of the sample (in mm);

b is the width of the sample (in mm);

d is the thickness of the sample (in mm);

M_0 is the oven-dry mass (in g).

10 Test report

The test report shall give details of the following:

- a) the testing machine and apparatus used;
- b) the test programme;
- c) the relevant test data;
- d) the moisture content and relative density of each member;
- e) description of each failure;
- f) any special points having a bearing on the test results;
- g) a statement that testing has been carried out in accordance with this standard.

Section 2. Determination of withdrawal strength of category A fasteners

11 General

This section specifies methods of test for the determination of the withdrawal strength of category A fasteners in either timber or wood-based materials.

The requirements of section 1 shall be met.

12 Testing machines

The testing machines shall be in accordance with clause 3, and shall be arranged as shown in Figure 2.

13 Test programme

A detailed test programme shall be drawn up in accordance with clause 4 and the depth of penetration of the fastener into the specimens shall be defined (see 14.5) together with any requirements for pre-drilling, and projection of the fastener to provide adequate gripping during the test.

14 Test specimens

14.1 General

Test specimens shall be selected and conditioned in accordance with clauses 5 to 7.

14.2 Form and dimensions of specimens

The form and dimensions of the test specimens shall be as shown in Figure 1, and given in Table 1.

Table 2 — Fastener spacings for standard withdrawal test specimens (see Figure 1)

Fastener type	Fastener spacing	
	<i>a</i>	<i>b</i>
Nail and screw	$5d$	$20d$
Staple	$5d + 0.5c$	$20d + 0.5c$
NOTE <i>a</i> shall be not less than 20 mm; <i>b</i> shall be not less than 25 mm; <i>d</i> is the diameter of nail, screw or staple; <i>c</i> is the crown width of staple.		

14.3 Wood-based materials

Specimens in wood-based materials shall be produced from a single thickness (*t*) of the material (see Figure 1), and where the board material has a distinctive face and back, the fasteners shall be driven into the face.

14.4 Timber

Specimens of timber members shall be cut with the faces approximately parallel and perpendicular to the growth rings, and shall have a planed finish.

14.5 Penetration

Penetration of the fastener, in both timber and board material, shall be either:

a) seven times the nominal diameter of the fastener with a minimum penetration of 25 mm;

or, in the case of screw-type fasteners having a threaded length less than seven times their nominal diameter,

b) a depth equal to their threaded length;

or, in the case of nail-type fasteners having a length less than seven times their nominal diameter,

c) a depth equal to their length less a sufficient allowance for the test grip;

or, where board materials are too thin to permit the penetrations a) to c),

d) to the full board thickness.

15 Conditions of test

The conditions at test shall be in accordance with clause 8.

16 Procedure

16.1 Support each test specimen on the testing machine with the edge of the supports not closer to the embedded part of the fastener than 15 mm or three times the diameter of the embedded part, whichever is the greater.

16.2 Apply the withdrawal load at the underside of the head of the fastener at a continuous rate corresponding to a rate of movement of the machine cross-head of 2.5 ± 0.625 mm/min for a withdrawal of at least 10 mm.

16.3 Record the maximum load occurring throughout the test.

16.4 Determine the moisture content and relative density of the member in each specimen in accordance with clause 9.

17 Expression of results

The withdrawal strength is equivalent to the maximum load that occurs throughout the test as recorded in 16.3.

18 Test report

The test report shall be drawn up in accordance with clause 10.

Section 3. Determination of pull-through strength of category A fasteners

19 General

This section specifies methods of test for the determination of the pull-through strength of category A fasteners in either timber or wood-based materials.

The requirements of section 1 shall be met.

20 Testing machine

The testing machine shall be in accordance with clause 3 and shall be arranged as shown in Figure 3.

21 Test programme

A detailed test programme shall be drawn up in accordance with clause 4.

22 Test specimens

22.1 General

Test specimens shall be selected and conditioned in accordance with clauses 5 to 7. A suitable backing piece, which can be removed easily, shall be used to support the underside of the specimens during assembly.

22.2 Form and dimensions of specimens

22.2.1 Form. The specimens shall comprise a square or rectangular member of timber or wood-based material.

22.2.2 Dimensions. The thickness of timber members shall be:

- a) for nails and screws, five times their diameter, d , but not less than 12 mm;
- b) for staples, eight times their diameter, d , but not less than 12 mm.

The thickness of the wood-based material members shall be a standard production thickness.

The members of timber and wood-based material shall have side measurements which are the greater of 60 mm or the following:

- for nails — $40d$ parallel to grain of timber, otherwise $20d$;
- for screws — $20d$;
- for staples — parallel to crown: $40d + c$ parallel to grain of timber (where c is crown width of staple), otherwise $20d$;
— perpendicular to crown: $40d$ parallel to grain of timber, otherwise $20d$.

22.3 Wood-based materials

Specimens in wood-based materials shall be produced from a single thickness of the material, and where the board material has a distinctive face and back, the fasteners shall be driven into the face.

22.4 Timber

Timber members shall be cut with the faces approximately parallel and perpendicular to the growth rings, and shall have a planed finish.

22.5 Penetration

The fastener shall completely penetrate the specimen so as to allow the apparatus to be attached to the shank(s) of the fastener (see Figure 3).

22.6 Positioning fasteners

A single fastener shall be positioned centrally in the face of the specimen. Screws shall be inserted into pre-drilled holes of the same diameter as the screws. Staple type fasteners shall be tested with the crown parallel to and with the crown perpendicular to the grain of the timber, or to the face grain or long axis of the board material.

All fasteners shall be driven perpendicular to the specimen.

23 Conditions at test

The conditions at test shall be in accordance with clause 8.

24 Procedure

24.1 Place the test specimen in the test machine so that the fastener is supported all round with the support not closer to the nearest part of the fastener than 20 mm or the thickness of the member, whichever is the greater.

24.2 Apply the pull-through load to the shank(s) of the fastener at a continuous rate corresponding to a rate of movement of the machine cross-head of 2.5 ± 0.625 mm/min until either the pull-through occurs, the fastener breaks or the fastener penetrates 10 mm into the member.

24.3 Record the maximum load occurring throughout the test.

24.4 Determine the moisture content and relative density of the member in each specimen in accordance with clause 9.

25 Expression of results

The pull-through strength is equivalent to the maximum load that occurs throughout the test as recorded in 24.3.

26 Test report

The test report shall be drawn up in accordance with clause 10 and any pre-drilling used for fasteners other than screws shall be noted.

Section 4. General requirements for determination of lateral strength and stiffness

27 General

This section specifies general requirements for the determination of the lateral strength and stiffness of fasteners and shall be used in accordance with the detailed requirements for the different types of fastener given in sections 5 to 8. Requirements are given for both tension and compression loading, either of which may be used.

The requirements of section 1 shall be met.

NOTE Clauses 30 and 31 are technically equivalent to clause 8 of BS EN 26891:1991 (ISO 6891:1983) and since there is no conflict the procedure has been retained unchanged.

28 Testing machine

28.1 General

Where the loading in tension or compression is perpendicular to the grain of transverse members, the arrangement of the supports for the transverse members is specified for particular fasteners in the appropriate sections.

28.2 Tension loading

For loading in tension the testing machine may be fitted with either self-aligning grips or non self-aligning grips (see also 29.1).

28.3 Compression loading

For loading in compression the testing machine shall be fitted with spherically seated loading heads, or similar devices, to permit initial alignment of the test specimen to give uniform loading (see also 29.2).

28.4 Joint slip

For measuring joint slip the instruments used, and their attachment to the members, shall permit slip to be measured without interrupting the loading.

29 Test specimens

29.1 Specimens loaded in tension

For specimens loaded in tension in a testing machine fitted with self-aligning grips the length of the gripped members shall be such as to allow a minimum clear distance of 200 mm between the edge of the grip and the nearest part of the fastener or opposing member. If the grips are not self-aligning, the clear distance shall be 200 mm, or five times the thickness of the gripped member, whichever is the greater.

29.2 Specimens loaded in compression

The ends of the members which are to be loaded in compression shall be cut to give a flat surface at right angles to the member length.

29.3 Joint slip

Provision shall be made to measure joint slip (i.e. the relative movement of the members) of a specimen parallel to the direction of loading (see 28.4 and 30.1.3).

30 Procedure

30.1 Load test general procedure

30.1.1 Obtain and record an estimate of the average maximum load, F_{est} , for the particular type of specimen being tested.

NOTE This may be determined from experience, by calculation, or by a few preliminary load slip tests.

30.1.2 Apply the load at a constant rate of $0.2F_{est}$ per min up to $0.4F_{est}$, maintain this load for 30 s and then reduce the load to $0.1F_{est}$ at the same rate. Maintain this load for 30 s before increasing again at $0.2F_{est}$ per min to a load of $0.7F_{est}$. Thereafter maintain a constant rate of cross-head movement of the testing machine so that the maximum load F_{max} , is reached in a further 3 min to 5 min, to give a total loading time of 10 min to 15 min. (See Figure 4.)

30.1.3 Measure and record the joint slip at least at each increment and decrement of load of $0.1F_{est}$, as indicated in Figure 5. The measurements shall be made between corresponding points on opposite sides of the specimen and shall be averaged. The measurements shall be to an accuracy of 0.02 mm for slips up to 2 mm and to at least 1 % for the slips greater than 2 mm. See also clause 31.

30.1.4 If during testing the mean value of the maximum loads recorded for the tests already completed within a set, deviates by more 20 % from the estimated value F_{est} , then change the estimated value to the mean value, with corresponding adjustment to the load increments. The values of maximum load already recorded shall be accepted without correction. However, the slip values determined in 3) to 8) of clause 31 shall be adjusted to the final value of F_{est} for each set of tests.

30.1.5 Record the maximum test load F_{max} , throughout each test. Where the load is still increasing at a slip of 15 mm, record the load at this slip as the maximum load.

31 Expression of results

The lateral strength and stiffness shall be expressed in accordance with the following values which shall normally be calculated and recorded for each test.

1) maximum load	$F_{\max}$
2) estimated maximum load	F_{est}
3) initial slip	$v_i = v_{04}$
4) modified initial slip	$v_{i,\text{mod}} = 4(v_{04} - v_{01})/3$
5) joint settlement	$vs = v_i - v_{i,\text{mod}}$
6) elastic slip	$v_e = 2(v_{14} + v_{24} - v_{11} - v_{21})/3$
7) initial slip modulus	$k_i = 0.4F_{\text{est}}/v_i$
8) slip modulus	$k_s = 0.4F_{\text{est}}/v_{i,\text{mod}}$
9) slip at $0.6F_{\max}$	$v_{0.6}$
10) modified slip at $0.6F_{\max}$	$v_{0.6\text{ mod}} = v_{0.6} - v_{24} + v_{i,\text{mod}}$
11) slip at $0.8F_{\max}$	$v_{0.8}$
12) modified slip at $0.8F_{\max}$	$v_{0.8\text{ mod}} = v_{0.8} - v_{24} + v_{i,\text{mod}}$

NOTE If the load/slip curve is initially convex upwards the vs will be negative.

The values of 9) to 12) above apply to the actual value of $F_{\max}$ for each test. When a continuous load/slip diagram is available the values may be obtained directly. When only readings of slip at increments of F_{est} are available then the values shall be obtained by interpolation or extrapolation. See also **30.1.4**.