# British Standard

# Structural use of timber —

## Part 2: Code of practice for permissible stress design, materials and workmanship

ICS 91.080.20

# Committees responsible for this British Standard

The preparation of this part of BS 5268 was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/5, Structural use of timber, upon which the following bodies were represented:

Association of Consulting Engineers
British Cement Association
British Constructional Steelwork Association Ltd.
British Masonry Society
Building Employers' Confederation
Department of the Environment (Building Research Establishment)
Department of the Environment (Construction Sponsorship Directorate)
Department of Transport
Federation of Civil Engineering Contractors
Institution of Civil Engineers
Institution of Structural Engineers
National Council of Building Material Producers
Royal Institute of British Architects
Timber Research and Development Association

The following bodies were also represented in the drafting of the standard through subcommittees and panels:

British Woodworking Federation
Department of the Environment (Property and Buildings Directorate)
Health and Safety Executive
National House-Building Council
Timber Trade Federation

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# Foreword

This new edition of BS 5268-2 has been prepared by Subcommittee B/525/5. It incorporates some of the European Committee for Standardization (CEN) standards on materials to ease the specification and supply of materials during the period of coexistence of BS 5268 and Eurocode 5. For the sake of conformity there has been no renumbering of sections. BS 5268-2:2002 supersedes BS 5268-2:1996 which is withdrawn.

BS 5268 is published in the following parts and sections:

— *Part 2: Code of practice for permissible stress design, materials and workmanship;*

— *Part 3: Code of practice for trussed rafter roofs;*

— *Part 4: Fire resistance of timber structures;*

— *Section 4.1: Recommendations for calculating fire resistance of timber members;*

— *Section 4.2: Recommendations for calculating fire resistance of timber stud walls and joisted floor constructions;*

— *Part 5: Code of practice for the preservative treatment of structural timber;*

— *Part 6: Code of practice for timber frame walls;*

— *Section 6.1: Dwellings not exceeding four storeys;*

— *Section 6.2: Buildings other than dwellings;*

— *Part 7: Recommendations for the calculation basis for span tables;*

— *Section 7.1: Domestic floor joists;*

— *Section 7.2: Joists for flat roofs;*

— *Section 7.3: Ceiling joists;*

— *Section 7.4: Ceiling binders;*

— *Section 7.5: Domestic rafters;*

— *Section 7.6: Purlins supporting rafters;*

— *Section 7.7: Purlins supporting sheeting or decking.*

This new edition of BS 5268-2 incorporates technical changes only. It does not reflect a full review or revision of the standard, which will be undertaken in due course.

As a code of practice, BS 5268-2 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

BS 5268-2 was originally published as CP 112 in 1952 and revised in 1967. In 1971, during the metrication of the construction industry, CP 112-2 *Metric units* was published. Part 2, however, did not involve any change in technical content compared with part 1 (except as covered in amendments), having been produced simply by converting the units to the SI system. Both parts of CP 112 were subsequently withdrawn.

Since 1967 there have been continuing and significant changes affecting the structural use of timber in the UK. These include major changes in the system for grading timber and in the species used in the construction of plywood. Other wood-based materials are also increasingly being used in structural work.

Moreover, research in the UK and in other countries had shown the need for a review of the modification factors and stress values given in the code. Accordingly, these were revised in the 1984 edition to take account of the results of this research and to reflect the properties of construction materials then available in the UK.

Extensive amendment of CP 112-2:1971 had already dealt with some of these changes, but Technical Committee CSB/32, which was responsible for BS 5268, decided on a thorough revision of the whole series.

In the 1984 edition of BS 5268-2, the recommendations were based on the grading system referred to in BS 4978 which defines two visual and four machine grades, i.e. GS, SS, MGS, M50, MSS and M75. This superseded the previous system based on the numbered visual grades 75, 65, 50 and 40 to which no reference remains in BS 5268. The scope of work was extended to include information concerning additional species of tropical hardwood, grades of plywood and particular grades of tempered hardboard and wood particleboard which have been shown to be suitable for structural use.

Extending the scope of the standard meant including many more tables than in the previous standards and this in itself created difficulties. A system of strength classes for solid timber was introduced which provides a design alternative to the use of strength grade and species combinations.

The introduction of strength classes gives the specifier and supplier greater flexibility in the choice of species and grades which can be specified or offered.

In deriving the recommended stresses for timber in the 1984 edition, estimates of 5 % lower exclusion values of strength and stiffness (and not the 1 % values as in previous standards) were used. Furthermore, the modulus of elasticity values no longer included an element due to shear (i.e. “true” modulus of elasticity is tabulated, replacing the “apparent” modulus of elasticity used in CP 112). These changes were in accordance with the accepted definitions of characteristic values adopted for other materials.

The 1991 edition was produced principally to allow for the inclusion of information on particleboard grade stresses. It was also used to make other relatively minor changes, the major ones being to provide increased values of the modulus of elasticity for glued laminated timber in section **3**, and to correct errors and omissions in the 1988 edition.

The 1988 edition of BS 5268-2 listed grading agencies approved by Technical Committee CSB/32 in Appendices J, K, L and P. Since 1988, Technical Committee CSB/32 has relinquished the role of approving grading agencies. In its place, the UK Timber Grading Committee (UKTGC) has taken on that role. The UKTGC’s lists of approved grading agencies are not included in this edition of this part of BS 5268, but may be found in the document *Approved certification bodies for the supply of strength graded timber* [1] published by the Timber Trade Federation.

BS 5268-2 has been revised to provide a UK structural code to run in parallel with DD ENV 1995-1-1, *Eurocode 5: Design of timber structures — Part 1.1: General rules and rules for buildings (together with United Kingdom National Application Document),* during the period of its introduction as a DD ENV until its publication as an EN. The purpose is primarily to incorporate as many as possible of the CEN material standards specified in DD ENV 1995-1-1 to limit the number of material specifications and the associated problems caused to suppliers. The opportunity has also been taken to include parts of DD ENV 1995-1-1 that will benefit timber structures and increase the affinity between the two codes.

The overall aim has been to incorporate material specifications and design approaches from DD ENV 1995-1-1, whilst maintaining a permissible stress code with which designers, accustomed to BS 5268, will feel familiar and be able to use without difficulty.

The strength class system introduced in 1984 has been replaced in this edition with the CEN system, which has more classes. Tables giving the assignment of BS 4978 visual grades and North American visual and machine grades to strength classes are included. Timber machine graded in Europe in accordance with BS EN 519 is graded directly to the strength class boundaries and is marked with the strength class number.

Other features of this edition are:

— a revised range of imported plywood and the deletion of British hardwood plywood;

— the approach to nailed, screwed and bolted joints, which is that taken in DD ENV 1995-1-1;

— the replacement of the two service exposure conditions with the three service classes from DD ENV 1995-1-1;

— the inclusion of British grown oak to BS 5756:1997;

— recommendations on deriving grade stresses and moduli for certain types of plywoods and other wood based panel products;

— that sections dealing with tempered hardboard and C5 particleboard have been deleted and replaced with recommendations for the design of roofs and floor decking by testing.

BS 5268 remains, as hitherto, a document mainly for designers. In drafting it has been assumed that the design of timber structures is entrusted to chartered civil or structural engineers, or other suitably qualified persons and that the works are done under qualified supervision.

Attention is drawn to the Construction (Design and Management) Regulations 1994 [2] which require clients to appoint a planning supervisor. These regulations place statutory duties on clients, planning supervisors, designers and contractors to plan, coordinate and manage health and safety throughout all stages of a construction project.

The planning supervisor has overall responsibility for coordinating the health and safety aspects of the design and planning phase and for the initial stages of the health and safety plan and the health and safety file.

The designer has to design to avoid risks to the health and safety of those constructing, maintaining and demolishing the structure or, if avoidance is not possible, to reduce the risk. The designer has to ensure that information on health and safety is passed to the planning supervisor for inclusion in the health and safety plan and the health and safety file.

These regulations are referred to in the text of this British Standard.

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**

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# Section 1. General

## 1.1 Scope

BS 5268-2 provides guidance on the structural use of timber, glued laminated timber, plywood and other panel products in load-bearing members. It includes recommendations on quality, grade stresses and modification factors applicable to these materials when used as simple members, or as parts of built-up components, or as parts of structure incorporating other materials. It also gives recommendations for the design of nailed, screwed, bolted, dowelled, connectored and glued joints. In addition, it provides recommendations for a method of test to assess the adequacy of structural assemblies, and it includes general advice on workmanship, various treatments which can be applied, inspection and maintenance.

It does not, and it is not intended to, deal comprehensively with all aspects of timber construction. In particular it does not cover well tried and traditional methods of timber construction which have been employed successfully over a long period of time.

Compliance with the structural adequacy aspects of the Building Regulations can be achieved by following the recommendations of this standard or via National Technical Approvals Certificates.

## 1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

**Standards publications**

BS 449-2:1969, *Specification for the use of structural steel in building — Part 2: Metric units.*

BS 1202-1:1974, *Specification for nails — Part 1: Steel nails.*

BS 1204:1993, *Specification for type MR phenolic and aminoplastic synthetic resin adhesives for wood.*

BS 1210:1963, *Specification for wood screws.*

BS 1579:1960, *Specification for connectors for timber.*

BS 4320:1968, *Specification for metal washers for general engineering purposes — Metric series.*

BS 4978:1996, *Specification for softwood grades for structural use.*

BS 5268-5:1989, *Structural use of timber — Part 5: Code of practice for the preservative treatment of structural timber.*

BS 5756:1997, *Specification for tropical hardwoods graded for structural use.*

BS 6100-4.1:1992, *Glossary of building and civil engineering terms — Part 4: Forest products — Section 4.1: Characteristics and properties of timber and wood based panel products.*

BS 6100-4.2:1984, *Glossary of building and civil engineering terms — Part 4: Forest products — Section 4.2: Sizes and quantities of solid timber.*

BS 6100-4.3:1984, *Glossary of building and civil engineering terms — Part 4: Forest products — Section 4.3: Wood based panel products.*

BS 6100-4.4:1992, *Glossary of building and civil engineering terms — Part 4: Forest products — Section 4.4: Carpentry and joinery.*

BS 6100-4.5:1984, *Glossary of building and civil engineering terms — Part 4: Forest products — Section 4.5: Cork.*

BS 6150:1991, *Code of practice for painting of buildings.*

BS 6399-1:1996, *Loading for buildings — Part 1: Code of practice for dead and imposed loads.*

BS 6399-2, *Loading for buildings — Part 2: Code of practice for wind loads.*

BS 6399-3:1988, *Loading for buildings — Part 3: Code of practice for imposed roof loads.*

BS 6446:1997, *Specification for manufacture of glued structural components of timber and wood based panel products.*

BS 7916, *Code of practice for the selection and application of particleboard, oriented strand board (OSB), cement bonded particleboard and wood fibreboards for specific purposes.*

BS EN 300, *Oriented strand boards (OSB) — Definitions, classification and specifications.*

BS EN 301:1992, *Adhesives, phenolic and aminoplastic, for load-bearing timber structures: classification and performance requirements.*

BS EN 310:1993, *Wood-based products — Determination of modulus of elasticity in bending and of bending strength.*

BS EN 312-4, *Particleboards — Specifications — Part 4: Requirements for load-bearing boards for use in dry conditions.*

BS EN 312-5, *Particleboards — Specifications — Part 5: Requirements for load-bearing boards for use in humid conditions.*

BS EN 312-6, *Particleboards — Specifications — Part 6: Requirements for heavy duty load-bearing boards for use in dry conditions.*

BS EN 312-7, *Particleboards — Specifications — Part 7: Requirements for heavy duty load-bearing boards for use in humid conditions.*

BS EN 314-1:1993, *Plywood — Bonding quality — Part 1: Test methods.*

BS EN 314-2:1993, *Plywood — Bonding quality — Part 2: Requirements.*

BS EN 315:1993, *Plywood — Tolerances for dimensions.*

BS EN 322:1993, *Wood-based panels — Determination of moisture content.*

BS EN 323:1993, *Wood-based panels — Determination of density.*

BS EN 324-1:1993, *Wood-based panels — Determination of dimensions of boards — Part 1: Determination of thickness, width and length.*

BS EN 324-2:1993, *Wood-based panels — Determination of dimensions of boards — Part 2: Determination of squareness and edge straightness.*

BS EN 336:1995, *Structural timber — Coniferous and poplar — Sizes — Permissible deviations.*

BS EN 338:1995, *Structural timber — Strength classes.*

BS EN 380, *Timber structures — Test methods — General principles for static load testing.*

BS EN 385:1995, *Finger jointed structural timber — Performance requirements and minimum production requirements.*

BS EN 386:1995, *Glued laminated timber — Performance requirements and minimum production requirements.*

BS EN 518:1995, *Structural timber — Grading — Requirements for visual strength grading standards.*

BS EN 519:1995, *Structural timber — Grading — Requirements for machine strength graded timber and grading machines.*

BS EN 622-2, *Fibreboards — Specifications — Part 2: Requirements for hardboards.*

BS EN 622-3, *Fibreboards — Specifications — Part 3: Requirements for medium boards.*

BS EN 622-5, *Fibreboards — Specifications — Part 5: Requirements for dry process boards (MDF).*

BS EN 636-1, *Plywood — Specifications — Part 1: Requirements for plywood for use in dry conditions.*

BS EN 636-2, *Plywood — Specifications — Part 2: Requirements for plywood for use in humid conditions.*

BS EN 636-3, *Plywood — Specifications — Part 3: Requirements for plywood for use in exterior conditions.*

BS EN 789, *Timber structures — Test methods — Determination of mechanical properties of wood-based panels.*

BS EN 1058, *Wood-based panels — Determination of characteristic values of mechanical properties and density.*

BS EN 1195, *Timber structures — Test methods — Performance of structural floor decking.*

BS EN 12369-1, *Wood-based panels — Characteristic values for use in structural design — Part 1: OSB, particleboards and fibreboards.*

BS EN 12871, *Wood-based panels — Structural roof decking on joists.*

BS EN 12872, *Wood-based panels — Guidance for structural panel installation.*

BS EN 20898-1:1992, *Mechanical properties of fasteners — Part 1: Bolts, screws and studs.*

**Other references**

[4] CANADIAN STANDARDS ASSOCIATION (CSA). *Canadian softwood lumber*. CSA 0141-1994. Rexdale, Ontario: CSA, 1974[1].

[5] NATIONAL LUMBER GRADES AUTHORITY (NLGA). *National Grading Rules for Dimension Lumber*. Burnaby, BC: NLGA, 1994[1].

[6] NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY (NIST). *American softwood lumber*. NBS PS 20-70. Washington: NBS, 1986[2].

[7] NATIONAL GRADING RULES FOR DIMENSION LUMBER (NGRDL). *National Grading Rules for Softwood Dimension Lumber*. Portland, OR: West Coast Lumber Inspection Bureau (WCLIB), 1975[3].

[8] CANADIAN STANDARDS ASSOCIATION (CSA). *Canadian Douglas fir plywood*. CSA 0121-M1978. Rexdale, Ontario: CSA[1].

[9] CANADIAN STANDARDS ASSOCIATION. *Canadian softwood plywood.* CSA 0151-M1978. Rexdale, Ontario: CSA[1].

[10] NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY (NIST). PS1-95. *American construction and industrial plywood;* or from APA — The Engineered Wood Association, Tacoma; or from TECO Corporation, Madison. NBS PS 1-83. Tacoma: American Plywood Association (APA)[2].

[11] TECHNICAL RESEARCH CENTRE OF FINLAND (VTT). *Quality control contract.* Helsinki: VTT, 1977[4].

[12] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *General rules for the classification of plywood with outer plies of birch.* SFS 2412. Helsinki: SFS, 1971[5].

[13] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Quality requirements for appearance of plywood with outer plies of birch.* SFS 2413. Helsinki: SFS, 1971[5].

[14] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Finnish combi plywood.* SFS 4091. Helsinki: SFS, 1988[6].

[15] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Finnish conifer plywood.* SFS 4092. Helsinki: SFS, 1988[5].

[16] STANDARDISERINGSKOMMISSIONEN I SVERIGE (SIS). *Wood based sheet material — Manufacture and control of constructional boards.* SBN 1975:5[6].

[17] ECONOMIC COMMISSION FOR EUROPE (ECE). *Recommended standard for strength grading of coniferous sawn timber.* ECE Sawn timber. Geneva: United Nations (UN), 1982[7].

[18] NLGA, SOUTHERN PINE INSPECTION BUREAU (SPIB), WCLIB, WESTERN WOOD PRODUCTS ASSOCIATION (WWPA). *North American Export Standard for Machine Stress-rated Lumber*. Burnaby, BC: NLGA, April 1987 (and supplement No. 1, 1992)[8].

[19] GREAT BRITAIN. Building Regulations 1991. London: The Stationery Office[9].

[1] Available from Canada Wood U.K., PO Box 1, Farnborough, Hants GU14 6WE.
[2] Available from US Department of Commerce, Technology Administration, National Technical Information Service, Springfield VA 22161, USA.
[3] Available from American Softwoods representing Southern Pine and Softwood Exports Council, 26 Castle Street, High Wycombe, Bucks HP13 6RU.
[4] Available from VTT, PO Box 102 (Vuorimiehentie 5), SF-02150 Espoo, Finland.
[5] Available from SFS, Maistraatinportti 2, PO Box 116, FIN-00241 Helsinki, Finland.
[6] Available from SIS, Box 3295, 103 66 Stockholm, Sweden.
[7] Available from UB-ECE, Palais des Nations, CH-1211 Genève 10, Switzerland.
[8] Available from American Softwoods representing Southern Pine and Softwood Exports Council, 26 Castle Street, High Wycombe, Bucks HP13 6RU.
[9] Available from The Stationery Office, PO Box 276, London SW8 5DT.

[20] GREAT BRITAIN. Building Standards Scotland. Edinburgh: The Stationery Office, 1990[10].

[21] NORTHERN IRELAND. Building Regulations (Northern Ireland). Belfast: The Stationery Office, 1994[11].

[22] INSTITUTION OF STRUCTURAL ENGINEERS (ISE). *Appraisal of existing structures*. London: ISE, 1980[12].

## 1.3 Terms and definitions

For the purposes of BS 5268-2 the terms and definitions given in BS 6100 and the following apply.

**1.3.1**
**British grown timber**
timber grown within the United Kingdom

NOTE For the purposes of BS 5268-2, species grown in the Republic of Ireland are given the same rating as British grown timbers.

**1.3.2**
**connector**
device which when embedded in each or in one of the contact faces of two members held together by a connecting bolt, is capable of transmitting a load from one member to another

NOTE Connectors generally consist of a metal plate, disc or ring.

**1.3.3**
**connector axis**
line joining the centres of a pair of adjacent connectors located on the same surface

**1.3.4**
**end joint efficiency**
percentage ratio of the strength of the end joint to the strength of unjointed timber of the same cross-section and species containing no strength reducing characteristics

**1.3.5**
**glued laminated member**
timber structural member obtained by gluing together a number of laminations having their grain essentially parallel

**1.3.6**
**grade stress**
stress which can safely be permanently sustained by material of a specific section size and of a particular strength class or species and grade

**1.3.7**
**horizontally glued laminated member**
glued laminated member whose laminations are parallel to the neutral plane

**1.3.8**
**load-sharing system**
assembly of pieces or members which are constrained to act together to support a common load

**1.3.9**
**member**
structural component which may be either a piece of solid timber or built up from pieces of timber, plywood, etc.

NOTE Examples of members are floor joist, box beam and member in a truss.

[10] Available from The Stationery Office, 71 Lothian Road, Edinburgh EH3 9AZ.
[11] Available from The Stationery Office, 16 Arthur Street, Belfast BTI 4GD.
[12] Available from ISE, 11 Upper Belgrave Street, London SW1X 8BH.

**1.3.10**
**permissible stress**
stress that can safely be sustained by a structural material under a particular condition

NOTE For the purposes of BS 5268-2, the permissible stress is the product of the grade stress and the appropriate modification factors for section size, service class and loading.

**1.3.11**
**principal member**
individual member on which the integrity of the structure depends

NOTE An example of a principal member is a trimmer beam.

**1.3.12**
**steel dowel**
plain solid steel cylindrical bar

**1.3.13**
**strength class**
classification of timber based on particular values of grade stress, modulus of elasticity and density

**1.3.14**
**structural unit**
assembly of members forming the whole or part of a framework

NOTE Examples of structural units are truss, prefabricated floor and wall, and skeleton of a building or a complete structure.

**1.3.15**
**target size**
size used to indicate the size desired (at 20 % moisture content), and used, without further modification, for design calculations

NOTE The tolerance classes for use with the target size are given in BS EN 336.

**1.3.16**
**vertically glued laminated member**
glued laminated member whose laminations are at right angles to the neutral plane

## 1.4 Symbols

The symbols used in BS 5268-2 are based on ISO 3898, supplemented by the recommendations of CIB-W18-1 published as *Symbols for use in structural timber design* [3], which takes particular account of timber properties.

For the purposes of BS 5268-2 the following symbols apply.

| | |
|---|---|
| $a$ | distance; |
| $A$ | area; |
| $b$ | breadth of beam; thickness of web; lesser transverse dimension of a tension or compression member; |
| $d$ | diameter; |
| $E$ | modulus of elasticity; |
| $F$ | force or load; |
| $h$ | depth of member, greater transverse dimension of a tension or compression member; |
| $i$ | radius of gyration; |
| $K$ | modification factor (always with a subscript);<br>NOTE See Annex L for a full list of modification factors used in BS 5268-2. |
| $L$ | length; span; |
| $m$ | mass; |
| $M$ | bending moment; |
| $n$ | number; |
| $r$ | radius of curvature; |
| $t$ | thickness; thickness of laminations; |
| $u$ | fastener slip; |
| $\alpha$ | angle between the direction of the load and the direction of the grain; |
| $\eta$ | eccentricity factor; |
| $\theta$ | angle between the longitudinal axis of a member and a connector axis; |
| $\lambda$ | slenderness ratio; |
| $\sigma$ | stress; |
| $\tau$ | shear stress; |
| $\omega$ | moisture content. |

The subscripts used are:

a) type of force, stress, etc.:

| | |
|---|---|
| c | compression; |
| m | bending; |
| t | tension; |

b) significance:

| | |
|---|---|
| a | applied; |
| adm | permissible; |
| e | effective; |
| mean | arithmetic mean; |

c) geometry:

| | |
|---|---|
| apex | apex; |
| r | radial; |
| tang | tangential; |
| $\parallel$ | parallel (to the grain); |
| $\perp$ | perpendicular (to the grain); |
| $\alpha$ | angle. |

It is recommended that where more than one subscript is used, the categories should be separated by commas.

Subscripts may be omitted when the context in which the symbols are used is unambiguous except in the case of modification factor, $K$.

## 1.5 Materials

All structural timber should be graded under the supervision of and bear the mark of a certification body approved for that purpose by the UK Timber Grading Committee.

NOTE All approved certification bodies are given in a list published by the Timber Trade Federation [1] and it is the products covered by, and bearing the marks of these certification bodies, to which this part of BS 5268 refers.

The materials used should conform to the following standards:

BS 449, BS 1202, BS 1203, BS 1204, BS 1210, BS 1579, BS 4978, BS 5669, BS 5756, BS EN 301, BS EN 336, BS EN 338, BS EN 518, BS EN 519

or to accepted standards from other countries, where the rules given in items a) to h) apply to timber and plywood graded outside the UK in accordance with other than UK rules.

a) The grading rules promulgated in accordance with CSA (Canadian Standards Association) 0141-1994, *Canadian softwood lumber* [4], and approved by the Canadian Lumber Standards Accreditation Board (CLSAB) are the *National Grading Rules for Dimension Lumber,* National Lumber Grades Authority (NLGA), 1994 [5].

b) The grading rules promulgated in accordance with NBS (National Bureau of Standards) PS 20-70, *American softwood lumber* [6], and approved by the American Lumber Standards Board of Review are the *National Grading Rules for Softwood Dimension Lumber,* National Grading Rules for Dimension Lumber (NGRDL), 1975 [7].

c) CSA 0121-M 1978, *Canadian Douglas fir plywood* [8], and CSA 0151-M 1978, *Canadian softwood plywood* [9], refer to those products covered by, and bearing the mark of, the Canadian Plywood Association (CANPLY) Plywood Manufacturing Standards.

d) NBS PS 1-95, *American construction and industrial plywood* [10], refers to those products covered by, and bearing the mark of, the APA, the Engineered Wood Association or TECO Corporation (TECO).

e) The following standards refer to those products covered by the *Quality control contract* [11] and bearing the mark of the Technical Research Centre of Finland (VTT): Finnish Standards SFS 2412, *General rules for the classification of plywood with outer plies of birch* [12], SFS 2413, *Quality requirements for appearance of plywood with outer plies of birch* [13], SFS 4091, *Finnish combi plywood* [14], and SFS 4092, *Finnish conifer plywood* [15], and British Standards BS EN 310, BS EN 314, BS EN 315, BS EN 322, BS EN 323 and BS EN 324.

f) Swedish Standard SBN 1975.5, *Wood based sheet material — Manufacture and control of constructional boards* [16], refers to those products covered by, and bearing the mark of, Boverket (see Figure E.4) and conforming to BS EN 314, BS EN 315 and BS EN 636-3.

g) Economic Commission for Europe (ECE) Sawn timber (1982) *Recommended standard for strength grading of coniferous sawn timber* [17].

h) The *North American Export Standard for Machine Stress-rated Lumber,* April 1987 (and supplement No. 1, 1992) [18], produced by the NLGA, Southern Pine Inspection Bureau (SPIB), West Coast Lumber Inspection Bureau (WCLIB) and Western Woods Products Association (WWPA) is approved by the CLSAB and the American Lumber Standards Board of Review.

## 1.6 Design considerations

### 1.6.1 General

**1.6.1.1** All structural members, assemblies or frameworks in a building, in combination with the floors and walls and other parts of a building, should be capable of sustaining, with due stability and stiffness and without exceeding the relevant limits of stress given in BS 5268-2, the whole dead, imposed and wind loading and all other types of loading referred to in BS 5268.

The design requirements of BS 5268-2 should be satisfied either by calculation, using the laws of structural mechanics, or by load testing in accordance with section **8**.

The design and details of parts and components should be compatible, particularly in view of the increasing use of prefabricated components such as trussed rafters and floors. The designer responsible for the overall stability of the structure should ensure this compatibility even when some or all of the design and details are the work of another designer.

To ensure that a design is robust and stable:

a) the geometry of the structure should be considered;

b) required interaction and connections between timber load bearing elements and between such elements and other parts of the structure should be assured;

c) suitable bracing or diaphragm effect should be provided in planes parallel to the direction of the lateral forces acting on the whole structure.

In addition, the designer should state in the health and safety plan (see foreword) any special precautions or temporary propping necessary at each and every stage in the construction process to ensure overall stability of all parts of the structure.

The grade stresses for materials and basic loads for fasteners given in BS 5268-2 apply to specific conditions and should be multiplied by the appropriate modification factors given in BS 5268-2 when the actual service and loading conditions are different.

NOTE The strength properties of timber, plywood, fibreboard, wood particleboard and joints are influenced by service and loading conditions.

**1.6.1.2** With regard to the design process, design, including design for construction durability and use in service, should be considered as a whole.

NOTE Unless clearly defined standards for materials, production, workmanship and maintenance are provided and complied with the design intentions may not be realized.

**1.6.1.3** With regard to basic assumptions covering durability, workmanship and materials, the quality of the timber and other materials, and of the workmanship as verified by inspections, should be adequate to ensure safety, serviceability and durability.

### 1.6.2 Loading

For the purpose of design, loading should be in accordance with BS 6399-1, BS 6399-2 and BS 6399-3 and CP 3:Chapter V-2 or other relevant standards, where applicable.

### 1.6.3 Accidental damage (including exceptional snow drift loads)

In addition to designing a structure to support loads arising from normal use, there should be a reasonable probability that the structure will not collapse catastrophically because of misuse or accident. No structure can be expected to be resistant to the excessive loads or forces that could arise from an extreme cause, but it should not be damaged to an extent that is disproportionate to the original cause.

Whilst the possibility of accidental damage or misuse of a structure should be considered, specific robustness design requirements are not usually necessary for buildings not exceeding four storeys, other than those requirements applicable to normal use (see **1.6.1.1**). However, for buildings exceeding four storeys, the recommendations for reducing the sensitivity of the structure to disproportionate collapse in the event of an accident given in section **5** of Approved Document A to the Building Regulations 1991 [19] (applicable to England and Wales), and in the Building Standards Scotland 1990 [20] and the Building Regulations (Northern Ireland) 1994 [21] should be followed.

The effects of exceptional loads caused by “local drifting of snow” on roofs, as defined in BS 6399-3 should, regardless of the number of storeys, be checked on the assumption that such loads are accidental.

Because of the particular occupancy of a structure (e.g. flour mill, chemical plant), it may be necessary to consider the effect of particular hazards and to ensure that, in the event of an accident, there is an acceptable probability of the structure continuing to perform its main function after the event, even if in a damaged condition. Vital load bearing structural members and any bollards, walls, retaining earth banks or the like which have been provided to prevent damage to those vital load bearing structural members, should be recorded as being essential structural elements in the health and safety file (see Foreword).

When considering the probable effects of misuse, accident or particular hazards, or when computing the residual stability of the damaged structure, the designer should normally multiply the values recommended in BS 5268-2 for all long-term permissible stresses and permissible loads on fasteners by a factor of two.

### 1.6.4 Service classes

Because of the effect of moisture content on material mechanical properties, the permissible property values should be those corresponding to one of the following service classes.

a) Service class 1 is characterized by a moisture content in the materials corresponding to a temperature of 20 °C and the relative humidity of the surrounding air only exceeding 65 % for a few weeks per year. In such moisture conditions most timber will attain an average moisture content not exceeding 12 %.

b) Service class 2 is characterized by a moisture content in the materials corresponding to a temperature of 20 °C and the relative humidity of the surrounding air only exceeding 85 % for a few weeks per year. In such moisture conditions most timber will attain an average moisture content not exceeding 20 %.

c) Service class 3, due to climatic conditions, is characterized by higher moisture contents than service class 2.

For the moisture contents of panel products (other than plywood) in service classes see BS 7916.

NOTE Timber continuously exposed to wet and hot conditions, e.g. in cooling tower structures, is outside the scope of BS 5268-2 as regards exposure conditions.

### 1.6.5 Moisture content

To reduce movement and creep under load, the moisture content of timber and wood-based panels when installed should be close to that likely to be attained in service.

Timber when sawn from the log has a high moisture content and, apart from external uses, should be dried before grading and installation (see Table 1). Where visual or machine strength graded timber is to be used in service classes 1 or 2, fissures and distortions should be assessed by the grading company at a moisture content of 20 % or lower, with no reading to exceed 24 % moisture content [see **2.5**f)].

NOTE Because it is difficult to dry thick timber, these recommendations do not apply to timber that has a target thickness of 100 mm or more (see **2.6.1**).

**Table 1 — Moisture content of timber related to service class**

| Service class (as defined in **1.6.4**) | Examples of end use of timber in building | Average moisture content likely to be attained in service conditions [a] % |
|---|---|---|
| 3 | External uses, fully exposed | 20 or more |
| 2 | Covered and generally unheated | 18 |
| 2 | Covered and generally heated | 15 |
| 1 | Internal uses, in continuously heated building | 12 |

[a] Moisture content should be measured using a moisture meter with insulated probes inserted 20 mm or one-quarter of the timber thickness, whichever is the lesser.

Wood based panel products have a relatively low moisture content at the time of manufacture. If expansion in use is likely to be a problem in a particular end-use situation, they should be conditioned to a higher moisture content before installation.

Care should be taken on site to ensure that material supplied in a dry condition is adequately protected from the weather (see **7.5**).

The moisture content of timber used in the manufacture of glued laminated members should conform to BS EN 386.

The moisture content of timber to be finger jointed should conform to BS EN 385.

The moisture content of materials used in components manufactured from separate pieces of timber, plywood and other panel products that are fastened together with glue (e.g. box beams, single web beams, stressed skin panels, glued gussets) should conform to BS 6446.

Timber treated with a water-borne preservative should be dried before being used in a structure whose design has been based on use in service classes 1 and 2.

### 1.6.6 Duration of loading

The grade stresses and the joint strengths given in BS 5268-2 are applicable to long-term loading. Because timber and wood-based materials can sustain a much greater load for a period of a few minutes than for a period of several years, the grade stresses and the joint loads may be increased for other conditions of loading by the modification factors given in the appropriate sections of BS 5268-2.

### 1.6.7 Section size

The bending, tension and compression stresses and the moduli of elasticity given in BS 5268-2 are applicable to material:

a) 300 mm deep (or wide, for tension) if assigned to a strength class or if graded in accordance with BS 4978, BS 5756 or NLGA or NGRDL joist and plank, structural light framing, light framing or stud rules;

b) of the particular section size quoted if graded to North American machine stress-rated (MSR) rules.

Because these properties of timber are dependent on section size and size related grade effects, the grade stresses should be modified for section sizes other than the sizes given in item a) by the modification factors given in the appropriate sections of BS 5268-2.

If material is graded to North American MSR rules, the grade stresses should not be modified for section size.

NOTE 1 Timber sizes normally available in the UK are given in the National annex to BS EN 336.

NOTE 2 BS 4978 and BS EN 519 give size limitations for solid timber and glulam.

### 1.6.8 Load-sharing systems

The grade stresses given in BS 5268-2 are applicable to individual pieces of structural timber. Where a number (see appropriate sections of BS 5268-2) of pieces of timber at a maximum spacing of 610 mm centre to centre act together to support a common load, then some modification of these stresses is permitted in accordance with the appropriate sections of BS 5268-2.

### 1.6.9 Effective cross-section

For the purpose of calculating the strength of a member at any section, the effective cross-section should be taken as the target size (with no adjustment for in-service moisture content) less due allowance for the reduction in area caused by sinkings, notches, bolt, dowel or screw holes, mortices, etc., either at that section or within such a distance from it as would affect the strength at that section.

### 1.6.10 Structural members

Structural members should be so proportioned that the stresses or deformation induced by all relevant conditions of loading do not exceed the permissible stresses or deformation limits for the material or the service conditions, determined in accordance with BS 5268-2.

### 1.6.11 Structural frameworks

#### 1.6.11.1 *Centroidal lines*

The design should take due account of secondary moments induced by eccentricity if the longitudinal axes of members do not intersect at joints.

NOTE The recommendations for trussed rafters appear in BS 5268-3.

#### 1.6.11.2 *Secondary stresses*

Many triangulated frameworks have continuous members and rigid or partially rigid joints. Due account should be taken of the secondary stresses present in such frameworks.

#### 1.6.11.3 *Provision of camber*

Where deflection of the framework would have an adverse effect on the function or appearance of the structure, the designer should specify any necessary camber to ensure the intended configuration after application of the appropriate load.

### 1.6.12 Floor and roof boarding

#### 1.6.12.1 *Lateral distribution of load*

Floor and roof boarding should be designed for the uniformly distributed and concentrated imposed loadings given in BS 6399-1.

The concentrated load should be considered to act over a 300 mm width of boarding where the boards are tongued and grooved. On pitched roofs where the boarding is not tongued and grooved the same rule should be applied. In all other instances the concentrated load should be applied to a single board.

If a wood strip, hardboard, wood particleboard or plywood wearing surface is applied on top of the boarding, or plywood sheathing on the underside, this should be considered as giving adequate lateral distribution of load and the above restriction is unnecessary.

#### 1.6.12.2 *Joints in boarding*

Header joints should be staggered and should bear directly on a supporting member with adequate bearing thereon, unless end-matched and taken into account in design.

*blank*

# Section 2. Timber

## 2.1 General

This section gives recommendations for the structural use of the softwood and hardwood species and species combinations given in Annex A. Guidance is also provided in **2.2** for the benefit of both specifiers and suppliers to help ensure greater consistency and uniformity of timber specifications.

## 2.2 Timber specification

Specifiers should consider and, where necessary, specify requirements under each of the following headings. All relevant standards should be referenced.

— Strength class or grade and species (see **1.5**, **2.3**, **2.5** and **2.6.1**).

— Size and surface condition (see **1.6.7** and **2.4**). Service class or moisture content (see **1.6.4** and **1.6.5**).

— Durability (see BS 5268-5).

— Special requirements. These may include more restrictive grade requirements for distortion, wane and marking, for example.

## 2.3 Species

Many factors are involved in the choice of species, but from the purely structural view it is the grade stresses which are of prime importance. These differ for each species and grade. To provide an alternative method of specification for the designer and specifier, and greater flexibility of supply, BS 5268-2 gives a series of strength classes which for design use can be considered as being independent of species and grade. Guidance as to which species and grades satisfy the strength requirements for each class is given in Table 2, Table 3, Table 4, Table 5, Table 6 and Table 7. For some applications it may be necessary to specify particular species (or exclude them) from within a strength class to take account of particular characteristics, e.g. natural durability, amenability to preservatives (see BS 5268-5), glues and fasteners. This may be particularly important for hardwoods as they tend to be more diverse in the properties that do not influence their strength class assignment.

The strength properties for timber meeting the requirements for strength classes (see **2.6.1**) are given in Table 8.

Mechanical properties for visual grades of individual species are given in Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15.

Species listed in Table 10 may be machine graded, in accordance with BS EN 519, to conform directly to the strength requirements for strength classes, provided machine settings are available. In addition, radiata pine, South African pine and Zimbabwean pine may be machine strength graded in accordance with BS EN 519 to conform directly to the strength requirements for strength classes. Machine settings should be issued by a certification body approved in accordance with **2.5**.

When it is obtained from the USA, the species mix (see Table A.1) for spruce-pine-fir (S-P-F) is slightly different from that supplied from Canada. When obtained from the USA it is denoted as S-P-F (South) or S-P-Fs.

## 2.4 Dimensions and geometrical properties

Timber structures can be designed using any size of timber. However, since the specific use is normally not known at the time of conversion, sawmills supplying the UK produce timber in a range of "customary" sizes. For the NLGA and NGRDL structural light framing (SLF), light framing (LF) and stud grades the customary sizes are 38 mm × 89 mm, 38 mm × 38 mm, 38 mm × 63 mm, 63 mm × 63 mm, 63 mm × 89 mm and 89 mm × 89 mm, with 38 mm × 114 mm and 38 mm × 140 mm also available in the Stud grade. For other grades, tables giving the customary sizes are given in the National annex of BS EN 336.

Specifications should refer to a published standard which limits permissible deviations for dimensions. Such a standard is BS EN 336 which also gives adjustments for changes in moisture content. In BS EN 336, cross-section dimensions are referred to as "target sizes" for which there are two tolerance classes: class 1, which is more appropriate to sawn surfaces, and class 2, for planed surfaces.

For design purposes, the effective cross-section and geometrical properties of a structural member should be calculated using the target size. The permitted deviations for tolerance class 1 are –1 mm to +3 mm for thicknesses and widths up to and including 100 mm and –2 mm to +4 mm for thicknesses and widths greater than 100 mm, and for tolerance class 2, ±1 mm for thicknesses and widths up to and including 100 mm, and ±1.5 mm for thicknesses and widths greater than 100 mm.

The required target size of members should be included in specifications, designs and drawings.

NOTE 1 Tolerance class 1 and tolerance class 2 may be referred to in an abbreviated form as "T1" and "T2", respectively, in specifications [e.g. 35(T2) × 97(T2)].

NOTE 2 As an aid to construction, the width (and/or sometimes the thickness) of sawn timber is reduced to produce timber of an accuracy that meets the requirements of tolerance class 2. In this case, the reduced width is the target size with a corresponding change in tolerance class [e.g. 47(T1) × 195(T2)].

Where sawn timber dimensions and tolerances are specified in accordance with a standard other than BS EN 336, then the target sizes should be calculated from the maximum minus deviation permitted by the standard by adding 1 mm for dimensions not exceeding 100 mm and 2 mm for dimensions over 100 mm. For processed timber, the target sizes should be calculated from the maximum minus deviation permitted by the standard by adding 1 mm for dimensions not exceeding 100 mm and 1.5 mm for dimensions over 100 mm. Generally, however, it is less economic to specify sizes other than those recommended in the National annex of BS EN 336.

## 2.5 Grades

All timber used for structural work should be strength graded by either an approved strength grading machine operated in accordance with the requirements of items e), or d) and f), or by visual inspection in accordance with the requirements of items a) or c), or b) and f). Visual and machine strength grading should be carried out under the control of a third party certification body approved by the UK Timber Grading Committee and given in a list published by the Timber Trade Federation. Grading machines should be approved by the UK Timber Grading Committee. Any modification to an approved grading machine should be promptly notified to and assessed by an expert[13] nominated by the UK Timber Grading Committee. The stresses given in this part of BS 5268 apply only to timber graded in accordance with the following rules and to the grades indicated.

a) BS 4978, for the visual grades designated GS and SS. The S6 and S8 grades of the ECE *Recommended standard for strength grading of coniferous sawn timber* (1982) [17] may be substituted for GS and SS, respectively.

b) *National grading rules for dimension lumber,* NLGA, 1994 [5] and the *National grading rules for softwood dimension lumber,* NGRDL, 1975 [7] for the grades designated:

1) Structural joists and planks — Select structural (Sel), No. 1, No. 2 and No. 3;

2) Structural light framing — Select structural (Sel), No. 1, No. 2 and No. 3;

3) Light framing — Construction (Const), standard (Std) and utility (Util);

4) Stud.

c) BS 5756, for the visual grade designated HS for tropical hardwoods and TH1, TH2, THA and THB for temperate hardwoods. Grades THA and THB are only available in cross-section sizes with no dimension less than 100 mm and cross-section areas greater than 20 000 mm$^2$.

d) *North American Export Standard for Machine Stress-rated Lumber* [18], for the machine grades designated 900f-1.0E, 1200f-1.2E, 1450f-1.3E, 1650f-1.5E, 1800f-1.6E, 1950f-1.7E and 2100f-1.8E.

e) Machine graded timber, other than as specified in item d), should meet the requirements of BS EN 519. This timber is graded directly to the strength class boundaries and marked accordingly.

f) For timber to be used in service classes 1 and 2, the assessment of fissures and distortion by the grader should be made with the timber dried to an average moisture content of 20 % or lower with no reading being in excess of 24 % and this timber should be marked "DRY" or "KD"[14] (see also **2.6.1**).

[13] At the time of publication of this standard, the nominated expert is the Building Research Establishment, Garston, Watford WD2 7JR.

[14] KD = kiln dried.

## 2.6 Grade stresses for strength classes and individual species

### 2.6.1 General

Grade stresses for service classes 1 and 2 are given in Table 8 for 16 strength classes, and in Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 for individual softwood and hardwood species and grades.

Because it is difficult to dry thick timber, service class 3 stresses and moduli should normally be used for solid timber members more than 100 mm thick, unless they are specially dried.

Designs should be based either on the stresses for the strength classes, or on those for the individual species and grades.

For designs based on strength classes, the material specification should indicate the strength class, whether softwood or hardwood, or, if the choice of material is limited by factors other than strength, the particular species required. The species and visual grades which meet the requirements of the strength classes are given in Table 2, Table 3, Table 4, Table 5, Table 6 and Table 7. Machine graded timber, meeting the requirements of BS EN 519, is graded directly to the strength class boundaries and marked accordingly.

A species and grade combination has been assigned to a strength class if the bending stress, mean modulus of elasticity and characteristic density (as defined in BS EN 338) for the combination, and appropriate to a depth (or width for tension) of 300 mm, are not less than the class values.

It should be noted that material cost usually rises with the grade, and general availability may be reduced. The use of the lowest strength class or strength grade may not, however, result in the most economical design, and reference should be made to commercial sources for information on the availability, grades, quantities, dimensions and costs of particular specifications.

### 2.6.2 Service class 3 (wet exposure) stresses

Grade stress values for service class 3 should be obtained by multiplying the tabulated stresses and moduli given in Table 8, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 by the modification factor $K_2$ from Table 16.

**Table 2 — Softwood combinations of species and visual grade which satisfy the requirements for various strength classes. Timber graded in accordance with BS 4978**

| Standard name | Strength class | | | | | | |
|---|---|---|---|---|---|---|---|
| | C14 | C16 | C18 | C22 | C24 | C27 | C30 |
| Imported: | | | | | | | |
| Parana pine | | GS | | | SS | | |
| Caribbean pitch pine | | | GS | | | SS | |
| redwood | | GS | | | SS | | |
| whitewood | | GS | | | SS | | |
| western red cedar | GS | | SS | | | | |
| Douglas fir-larch (Canada) | | GS | | | SS | | |
| Douglas fir-larch (USA) | | GS | | | SS | | |
| hem-fir (Canada) | | GS | | | SS | | |
| hem-fir (USA) | | GS | | | SS | | |
| spruce-pine-fir (USA) | | GS | | | SS | | |
| spruce-pine-fir (Canada) | | GS | | | SS | | |
| Sitka spruce (Canada) | GS | | SS | | | | |
| western white woods (USA) | GS | | SS | | | | |
| southern pine (USA) | | | GS | | SS | | |
| British grown: | | | | | | | |
| Douglas fir | GS | | SS [a] | | | | |
| larch | | GS | | | SS | | |
| British pine | GS | | | SS | | | |
| British spruce | GS | | SS | | | | |

NOTE 1 The S6 and S8 grades of the ECE *Recommended standard for strength grading of coniferous sawn timber* (1982) [17] may be substituted for GS and SS, respectively.

NOTE 2 A species/grade combination from a higher class (see Table 8) may be used where a lower class is specified.

[a] For sizes where the cross-sectional area exceeds 20 000 $mm^2$, SS grade British grown Douglas fir may be allocated to strength class C24.

**Table 3 — North American softwood species and grade combinations which satisfy the requirements for various strength classes. Timber graded in accordance with NLGA and NGRDL joist and plank rules**

| Standard name and origin | Strength class | | | | | | |
|---|---|---|---|---|---|---|---|
| | C14 | C16 | C18 | C22 | C24 | C27 | C30 |
| Douglas fir-larch (Canada) | | No. 1, No. 2 | | | Sel | | |
| Douglas fir-larch (USA) | | No. 1, No. 2 | | | Sel | | |
| hem-fir (Canada) | | No. 1, No. 2 | | | Sel | | |
| hem-fir (USA) | | No. 1, No. 2 | | | Sel | | |
| spruce-pine-fir (Canada and USA) | | No. 1, No. 2 | | | Sel | | |
| Sitka spruce (Canada) | No. 1, No. 2 | | Sel | | | | |
| western white woods (USA) | No. 1, No. 2 | | Sel | | | | |
| southern pine (USA) | | No. 3 | | No. 1, No. 2 | | | Sel |
| NOTE These classifications apply only to timber of a size not less than 38 mm × 114 mm. | | | | | | | |

**Table 4 — North American softwood and grade combinations which satisfy the requirements for various strength classes. Timber graded in accordance with NLGA and NGRDL structural light framing, light framing and stud rules**

| Standard name and origin | Strength class | | | | | |
|---|---|---|---|---|---|---|
| | C14 | C16 | C18 | C22 | C24 | C27 |
| Douglas fir-larch (Canada) | | No. 1, No. 2 | | | Sel | |
| Douglas fir-larch (USA) | | No. 1, No. 2 | | | Sel | |
| hem-fir (Canada) | | No. 1, No. 2 | | | Sel | |
| hem-fir (USA) | | No. 1, No. 2 | | | Sel | |
| spruce-pine-fir (Canada and USA) | | No. 1, No. 2 | | | Sel | |
| Sitka spruce (Canada) | No. 1, No. 2 | Sel | | | | |
| western white woods (USA) | No. 1, No. 2 | | Sel | | | |
| southern pine (USA) | | No. 3 | | No. 1, No. 2 | | Sel |
| Douglas fir-larch (Canada) | Const, Stud | | | | | |
| Douglas fir-larch (USA) | Const, Stud | | | | | |
| hem-fir (Canada) | Const, Stud | | | | | |
| hem-fir (USA) | Const, Stud | | | | | |
| spruce-pine-fir (Canada and USA) | Const, Stud | | | | | |
| Sitka spruce (Canada) | | | | | | |
| western white woods (USA) | | | | | | |
| southern pine (USA) | Std | Stud | Const | | | |
| NOTE A species/grade combination from a higher class may be used where a lower class is specified. | | | | | | |



**Table 5 — North American softwood species and grade combinations[a] which satisfy the requirements for various strength classes. Timber graded in accordance with North American machine stress-rated rules**

| Strength class | | | | | | |
|---|---|---|---|---|---|---|
| **C14** | **C16** | **C18** | **C22** | **C24** | **C27** | **C30** |
| 1200f-1.2E | 1450f-1.3E | | 1650f-1.5E | 1800f-1.6E | 1950f-1.7E | 2100f-1.8E |
| NOTE A species and grade combination from a higher strength class may be used where a lower class is specified. | | | | | | |

[a] This table is applicable only to the following species combinations:
- — Douglas fir-larch (Canada and USA);
- — hem-fir (Canada and USA);
- — spruce-pine-fir (Canada and USA);
- — southern pine (USA).

**Table 6 — Tropical hardwoods which satisfy the requirements for strength classes given in BS EN 338 when graded to HS grade in accordance with BS 5756:1997**

| Standard name | Strength class |
|---|---|
| iroko<br>jarrah<br>teak | D40 |
| merbau<br>opepe<br>karri<br>keruing | D50 |
| ekki<br>kapur<br>kempas | D60 |
| balau<br>greenheart | D70 |

**Table 7 — Temperate hardwoods which satisfy the requirements for strength classes graded to BS 5756:1997**

| Standard name | Grade | Strength class | Joints [a] |
|---|---|---|---|
| Oak | TH1 | D30 | D30 |
| | TH2 | see Table 15 | C24 |
| | THA [b] | D40 | D40 |
| | THB [b] | D30 | D30 |
| Sweet chestnut | TH1 | see Table 15 | C24 |

[a] This strength class is given only for the design of joints (alternatively Annex G may be used to calculate the joint strength of dowel type fasteners using the characteristic densities given in Table 15.

[b] Grades THA and THB are only obtainable in cross-section sizes with no dimension less than 100 mm and cross-section areas greater than 20 000 mm$^2$.

**Table 8 — Grade stresses and moduli of elasticity for various strength classes: for service classes 1 and 2**

| Strength class | Bending parallel to grain | Tension parallel to grain | Compression parallel to grain | Compression perpendicular to grain [a] | | Shear parallel to grain | Modulus of elasticity | | Characteristic density, $\rho_k$ [b] | Average density, $\rho_{mean}$ [b] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mean | Minimum | | |
| | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | kg/m$^3$ | kg/m$^3$ |
| C14 | 4.1 | 2.5 | 5.2 | 2.1 | 1.6 | 0.60 | 6 800 | 4 600 | 290 | 350 |
| C16 | 5.3 | 3.2 | 6.8 | 2.2 | 1.7 | 0.67 | 8 800 | 5 800 | 310 | 370 |
| C18 | 5.8 | 3.5 | 7.1 | 2.2 | 1.7 | 0.67 | 9 100 | 6 000 | 320 | 380 |
| C22 | 6.8 | 4.1 | 7.5 | 2.3 | 1.7 | 0.71 | 9 700 | 6 500 | 340 | 410 |
| C24 | 7.5 | 4.5 | 7.9 | 2.4 | 1.9 | 0.71 | 10 800 | 7 200 | 350 | 420 |
| C27 | 10.0 | 6.0 | 8.2 | 2.5 | 2.0 | 1.10 | 12 300 | 8 200 | 370 | 450 |
| C30 | 11.0 | 6.6 | 8.6 | 2.7 | 2.2 | 1.20 | 12 300 | 8 200 | 380 | 460 |
| C35 | 12.0 | 7.2 | 8.7 | 2.9 | 2.4 | 1.30 | 13 400 | 9 000 | 400 | 480 |
| C40 | 13.0 | 7.8 | 8.7 | 3.0 | 2.6 | 1.40 | 14 500 | 10 000 | 420 | 500 |
| D30 | 9.0 | 5.4 | 8.1 | 2.8 | 2.2 | 1.40 | 9 500 | 6 000 | 530 | 640 |
| D35 | 11.0 | 6.6 | 8.6 | 3.4 | 2.6 | 1.70 | 10 000 | 6 500 | 560 | 670 |
| D40 | 12.5 | 7.5 | 12.6 | 3.9 | 3.0 | 2.00 | 10 800 | 7 500 | 590 | 700 |
| D50 | 16.0 | 9.6 | 15.2 | 4.5 | 3.5 | 2.20 | 15 000 | 12 600 | 650 | 780 |
| D60 | 18.0 | 10.8 | 18.0 | 5.2 | 4.0 | 2.40 | 18 500 | 15 600 | 700 | 840 |
| D70 | 23.0 | 13.8 | 23.0 | 6.0 | 4.6 | 2.60 | 21 000 | 18 000 | 900 | 1 080 |

NOTE Strength classes C14 to C40 are for softwoods and D30 to D70 are for hardwoods.

[a] When the specification specifically prohibits wane at bearing areas, the higher values of compression perpendicular to grain stress may be used, otherwise the lower values apply.

[b] The values of characteristic density given above are for use when designing joints. For the calculation of dead load, the average density should be used.

**Table 9 — Grade and moduli of elasticity for special softwood strength classes: for service classes 1 and 2**

| Strength class | Bending parallel to grain N/mm² | Tension parallel to grain N/mm² | Compression parallel to grain N/mm² | Compression perpendicular to grain [a] N/mm² | | Shear parallel to grain N/mm² | Modulus of elasticity N/mm² | | Characteristic density [b], $\rho_k$ kg/m³ | Mean density, $\rho_{mean}$ kg/m³ |
|---|---|---|---|---|---|---|---|---|---|---|
| TR20 [c] | 6.6 | 4.0 | 7.3 | 2.3 | 1.7 | 0.82 | 9 000 | 6 000 | 340 | 410 |
| TR26 [c] | 10.0 | 6.0 | 8.2 | 2.5 | 2.0 | 1.10 | 11 000 | 7 400 | 370 | 450 |

[a] When the specification specifically prohibits wane at bearing areas, the higher values of compression perpendicular to grain stress may be used, otherwise the lower values apply.
[b] The values of characteristic density given above are for use when designing joints. For the calculation of dead load the average density should be used.
[c] The strength classes TR20 and TR26 are essentially for the design of trussed rafters but may be used for other applications with the grade stresses and moduli given above. For joints, the tabulated permissible loads for strength classes C18 and C27 should be used for TR20 and TR26 respectively.

**Table 10 — Grade stresses for softwoods graded in accordance with BS 4978: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain [a] | Tension parallel to grain [a] | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [b] | | Mean | Minimum |
| | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| redwood/whitewood | SS | 7.5 | 4.5 | 7.9 | 2.1 | 0.82 | 10 500 | 7 000 |
| (imported) | GS | 5.3 | 3.2 | 6.8 | 1.8 | 0.82 | 9 000 | 6 000 |
| British larch | SS | 7.5 | 4.5 | 7.9 | 2.1 | 0.82 | 10 500 | 7 000 |
| | GS | 5.3 | 3.2 | 6.8 | 1.8 | 0.82 | 9 000 | 6 000 |
| British pine | SS | 6.8 | 4.1 | 7.5 | 2.1 | 0.82 | 10 500 | 7 000 |
| | GS | 4.7 | 2.9 | 6.1 | 1.8 | 0.82 | 9 000 | 6 000 |
| British spruce | SS | 5.7 | 3.4 | 6.1 | 1.6 | 0.64 | 8 000 | 5 000 |
| | GS | 4.1 | 2.5 | 5.2 | 1.4 | 0.64 | 6 500 | 4 500 |
| Douglas fir | SS | 6.2 | 3.7 | 6.6 | 2.4 | 0.88 | 11 000 | 7 000 |
| (British grown) | GS | 4.4 | 2.6 | 5.2 | 2.1 | 0.88 | 9 500 | 6 000 |
| Parana pine | SS | 9.0 | 5.4 | 9.5 | 2.4 | 1.03 | 11 000 | 7 500 |
| (imported) | GS | 6.4 | 3.8 | 8.1 | 2.2 | 1.03 | 9 500 | 6 000 |
| pitch pine | SS | 10.5 | 6.3 | 11.0 | 3.2 | 1.16 | 13 500 | 9 000 |
| (Caribbean) | GS | 7.4 | 4.4 | 9.4 | 2.8 | 1.16 | 11 000 | 7 500 |
| western red cedar | SS | 5.7 | 3.4 | 6.1 | 1.7 | 0.63 | 8 500 | 5 500 |
| (imported) | GS | 4.1 | 2.5 | 5.2 | 1.6 | 0.63 | 7 000 | 4 500 |
| Douglas fir-larch | SS | 7.5 | 4.5 | 7.9 | 2.4 | 0.85 | 11 000 | 7 500 |
| (Canada and USA) | GS | 5.3 | 3.2 | 6.8 | 2.2 | 0.85 | 10 000 | 6 500 |
| hem-fir | SS | 7.5 | 4.5 | 7.9 | 1.9 | 0.68 | 11 000 | 7 500 |
| (Canada and USA) | GS | 5.3 | 3.2 | 6.8 | 1.7 | 0.68 | 9 000 | 6 000 |

[a] Stresses applicable to timber 300 mm deep (or wide); for other section sizes see **2.10.6** and **2.12.2**.
[b] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to grain stress may be multiplied by 1.33 and used for all grades.

**Table 10 — Grade stresses for softwoods graded in accordance with BS 4978: for service classes 1 and 2** (*continued*)

| Standard name | Grade | Bending parallel to grain [a] | Tension parallel to grain [a] | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [b] | | Mean | Minimum |
| | | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ |
| spruce-pine-fir | SS | 7.5 | 4.5 | 7.9 | 1.8 | 0.68 | 10 000 | 6 500 |
| (Canada and USA) | GS | 5.3 | 3.2 | 6.8 | 1.6 | 0.68 | 8 500 | 5 500 |
| Sitka spruce | SS | 6.6 | 4.0 | 7.0 | 1.7 | 0.66 | 10 000 | 6 500 |
| (Canada) | GS | 4.7 | 2.8 | 6.0 | 1.5 | 0.66 | 8 000 | 5 500 |
| western white woods | SS | 6.6 | 4.0 | 7.0 | 1.7 | 0.66 | 9 000 | 6 000 |
| (USA) | GS | 4.7 | 2.8 | 6.0 | 1.5 | 0.66 | 7 500 | 5 000 |
| southern pine | SS | 9.6 | 5.8 | 10.2 | 2.5 | 0.98 | 12 500 | 8 500 |
| (USA) | GS | 6.8 | 4.1 | 8.7 | 2.2 | 0.98 | 10 500 | 7 000 |

[a] Stresses applicable to timber 300 mm deep (or wide); for other section sizes see **2.10.6** and **2.12.2**.
[b] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to grain stress may be multiplied by 1.33 and used for all grades.

**Table 11 — Grade stresses for Canadian softwoods graded in accordance with NLGA rules: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain | Tension parallel to grain | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [a] | | Mean | Minimum |
| | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| Douglas fir-larch | J & P [b] and SLF | | | | | | | |
| | Sel | 8.0 | 6.2 | 8.8 | 2.7 | 0.93 | 12 500 | 8 500 |
| | No. 1 | 5.6 | 4.3 | 7.9 | 2.7 | 0.93 | 11 000 | 7 500 |
| | No. 2 | 5.6 | 4.3 | 6.9 | 2.4 | 0.93 | 11 000 | 7 500 |
| | No. 3 | 4.1 | 2.5 | 5.3 | 1.8 | 0.61 | 10 500 | 6 500 |
| | LF | | | | | | | |
| | Const | 4.7 | 2.8 | 6.1 | 2.7 | 0.93 | 11 000 | 7 500 |
| | Std | 3.5 | 2.1 | 4.6 | 2.4 | 0.93 | 10 500 | 7 000 |
| | Util | 2.8 | 1.7 | 3.4 | 1.8 | 0.61 | 10 500 | 7 000 |
| | Stud | 4.1 | 2.5 | 5.3 | 1.8 | 0.61 | 10 500 | 7 000 |
| hem-fir | J & P [b] and SLF | | | | | | | |
| | Sel | 8.0 | 6.2 | 8.8 | 2.1 | 0.71 | 12 000 | 8 500 |
| | No. 1 | 5.6 | 4.3 | 7.9 | 2.1 | 0.71 | 10 500 | 7 000 |
| | No. 2 | 5.6 | 4.3 | 6.9 | 1.8 | 0.71 | 10 500 | 7 000 |
| | No. 3 | 4.1 | 2.5 | 5.3 | 1.4 | 0.47 | 10 500 | 6 500 |
| | LF | | | | | | | |
| | Const | 4.7 | 2.8 | 6.1 | 2.1 | 0.71 | 10 500 | 7 000 |
| | Std | 3.5 | 2.1 | 4.6 | 1.9 | 0.71 | 10 500 | 7 000 |
| | Util | 2.8 | 1.7 | 3.4 | 1.4 | 0.47 | 10 500 | 7 000 |
| | Stud | 4.1 | 2.5 | 5.3 | 1.4 | 0.47 | 10 500 | 7 000 |

[a] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.
[b] J & P, Joist and Plank grades. Grading rules applicable to timber with cross-section dimensions greater than or equal to 38 mm × 114 mm.

**Table 11 — Grade stresses for Canadian softwoods graded in accordance with NLGA rules: for service classes 1 and 2** *(continued)*

| Standard name | Grade | Bending parallel to grain | Tension parallel to grain | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [a] | | Mean | Minimum |
| | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| spruce-pine-fir | J & P [b] and SLF | | | | | | | |
| | Sel | 8.0 | 6.2 | 8.8 | 1.8 | 0.68 | 10 500 | 7 000 |
| | No. 1 | 5.6 | 4.3 | 7.9 | 1.8 | 0.68 | 9 000 | 6 000 |
| | No. 2 | 5.6 | 4.3 | 6.9 | 1.6 | 0.68 | 9 000 | 6 000 |
| | No. 3 | 4.1 | 2.5 | 5.3 | 1.2 | 0.45 | 9 000 | 5 500 |
| | LF | | | | | | | |
| | Const | 4.7 | 2.8 | 6.1 | 1.8 | 0.68 | 9 000 | 6 000 |
| | Std | 3.5 | 2.1 | 4.6 | 1.6 | 0.68 | 9 000 | 6 000 |
| | Util | 2.8 | 1.7 | 3.4 | 1.2 | 0.45 | 9 000 | 6 000 |
| | Stud | 4.1 | 2.5 | 5.3 | 1.2 | 0.45 | 9 000 | 5 500 |
| Sitka spruce | J & P [b] and SLF | | | | | | | |
| | Sel | 7.1 | 5.5 | 7.8 | 1.7 | 0.66 | 10 000 | 6 500 |
| | No. 1 | 5.0 | 3.8 | 7.0 | 1.7 | 0.66 | 9 000 | 6 000 |
| | No. 2 | 5.0 | 3.8 | 6.1 | 1.5 | 0.66 | 9 000 | 6 000 |
| | No. 3 | 3.6 | 2.2 | 4.7 | 1.1 | 0.44 | 8 500 | 5 000 |
| | LF | | | | | | | |
| | Const | 4.2 | 2.5 | 5.4 | 1.7 | 0.66 | 8 500 | 6 000 |
| | Std | 3.1 | 1.9 | 4.0 | 1.5 | 0.66 | 8 500 | 5 500 |
| | Util | 2.5 | 1.5 | 3.0 | 1.1 | 0.44 | 8 500 | 5 500 |
| | Stud | 3.6 | 2.2 | 4.7 | 1.1 | 0.44 | 8 500 | 5 500 |

[a] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.
[b] J & P, Joist and Plank grades. Grading rules applicable to timber with cross-section dimensions greater than or equal to 38 mm × 114 mm.

**Table 12 — Grade stresses for USA softwoods graded in accordance with NGRDL rules: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain | Tension parallel to grain | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [a] | | Mean | Minimum |
| | | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² |
| Douglas fir-larch | J & P [b] and SLF | | | | | | | |
| | Sel | 8.0 | 6.2 | 8.8 | 2.4 | 0.85 | 11 000 | 8 000 |
| | No. 1 | 5.6 | 4.3 | 7.9 | 2.4 | 0.85 | 10 000 | 6 500 |
| | No. 2 | 5.6 | 4.3 | 6.9 | 2.2 | 0.85 | 10 000 | 6 500 |
| | No. 3 | 4.1 | 2.5 | 5.3 | 1.6 | 0.56 | 9 500 | 6 000 |
| | LF | | | | | | | |
| | Const | 4.7 | 2.8 | 6.1 | 2.4 | 0.85 | 10 000 | 6 500 |
| | Std | 3.5 | 2.1 | 4.6 | 2.2 | 0.85 | 9 500 | 6 500 |
| | Util | 2.8 | 1.7 | 3.4 | 1.6 | 0.56 | 9 500 | 6 500 |
| | Stud | 4.1 | 2.5 | 5.3 | 1.6 | 0.56 | 9 500 | 6 500 |
| hem-fir | J & P [b] and SLF | | | | | | | |
| | Sel | 8.0 | 6.2 | 8.8 | 1.9 | 0.68 | 11 000 | 8 000 |
| | No. 1 | 5.6 | 4.3 | 7.9 | 1.9 | 0.68 | 10 000 | 6 500 |
| | No. 2 | 5.6 | 4.3 | 6.9 | 1.7 | 0.68 | 10 000 | 6 500 |
| | No. 3 | 4.1 | 2.5 | 5.3 | 1.3 | 0.45 | 9 500 | 6 000 |
| | LF | | | | | | | |
| | Const | 4.7 | 2.8 | 6.1 | 1.9 | 0.68 | 10 000 | 6 500 |
| | Std | 3.5 | 2.1 | 4.6 | 1.7 | 0.68 | 9 500 | 6 500 |
| | Util | 2.8 | 1.7 | 3.4 | 1.3 | 0.45 | 9 500 | 6 500 |
| | Stud | 4.1 | 2.5 | 5.3 | 1.3 | 0.45 | 9 500 | 6 500 |

[a] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.
[b] J & P, Joist and Plank grades. Grading rules applicable to timber with cross-sectional dimensions greater than or equal to 38 mm × 114 mm.

**Table 12 — Grade stresses for USA softwoods graded in accordance with NGRDL rules: for service classes 1 and 2** *(continued)*

| Standard name | Grade | Bending parallel to grain | Tension parallel to grain | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [a] | | Mean | Minimum |
| | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| western white woods | J & P [b] and SLF | | | | | | | |
| | Sel | 7.1 | 5.5 | 7.8 | 1.7 | 0.66 | 9 000 | 6 000 |
| | No. 1 | 5.0 | 3.8 | 7.0 | 1.7 | 0.66 | 8 000 | 5 000 |
| | No. 2 | 5.0 | 3.8 | 6.1 | 1.5 | 0.66 | 8 000 | 5 000 |
| | No. 3 | 3.6 | 2.2 | 4.7 | 1.1 | 0.44 | 8 000 | 4 500 |
| | LF | | | | | | | |
| | Const | 4.2 | 2.5 | 5.4 | 1.7 | 0.66 | 8 000 | 5 000 |
| | Std | 3.1 | 1.9 | 4.0 | 1.5 | 0.66 | 8 000 | 5 000 |
| | Util | 2.5 | 1.5 | 3.0 | 1.1 | 0.44 | 8 000 | 5 000 |
| | Stud | 3.6 | 2.2 | 4.7 | 1.1 | 0.44 | 8 000 | 5 000 |
| southern pine | J & P [b] and SLF | | | | | | | |
| | Sel | 10.3 | 8.0 | 11.3 | 2.5 | 0.98 | 12 500 | 9 000 |
| | No. 1 | 7.2 | 5.5 | 10.2 | 2.5 | 0.98 | 11 500 | 7 500 |
| | No. 2 | 7.2 | 5.5 | 8.9 | 2.2 | 0.98 | 11 500 | 7 500 |
| | No. 3 | 5.3 | 3.2 | 6.8 | 1.7 | 0.64 | 11 000 | 6 500 |
| | LF | | | | | | | |
| | Const | 6.0 | 3.6 | 7.8 | 2.5 | 0.98 | 11 000 | 7 500 |
| | Std | 4.5 | 2.7 | 5.9 | 2.2 | 0.98 | 11 000 | 7 500 |
| | Util | 3.6 | 2.2 | 4.3 | 1.7 | 0.64 | 11 000 | 7 500 |
| | Stud | 5.3 | 3.2 | 6.8 | 1.7 | 0.64 | 11 000 | 7 000 |

[a] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.
[b] J & P, Joist and Plank grades. Grading rules applicable to timber with cross-sectional dimensions greater than or equal to 38 mm × 114 mm.

**Table 13 — Grade stresses for North American softwoods graded in accordance with North American MSR rules: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain [a] N/mm² | Tension parallel to grain N/mm² | Compression: Parallel to grain N/mm² | Compression: Perpendicular to grain [b] N/mm² | Shear parallel to grain N/mm² | Modulus of elasticity: Mean N/mm² | Modulus of elasticity: Minimum N/mm² |
|---|---|---|---|---|---|---|---|---|
| Douglas fir-larch | 900f-1.0E | 5.9 | 3.5 | 6.8 | 2.6 | 1.19 | 6 500 | 5 000 |
| | 1200f-1.2E | 7.9 | 4.7 | 7.7 | 2.6 | 1.19 | 8 000 | 6 500 |
| | 1450f-1.3E | 9.5 | 5.7 | 8.5 | 2.6 | 1.19 | 9 000 | 7 000 |
| | 1650f-1.5E | 10.8 | 6.5 | 9.0 | 2.6 | 1.19 | 10 500 | 8 500 |
| | 1800f-1.6E | 11.8 | 7.1 | 9.3 | 3.0 | 1.19 | 11 500 | 9 000 |
| | 1950f-1.7E | 12.8 | 7.7 | 9.6 | 3.0 | 1.19 | 12 000 | 9 500 |
| | 2100f-1.8E | 13.8 | 8.3 | 10.1 | 3.0 | 1.19 | 13 000 | 10 500 |
| hem-fir | 900f-1.0E | 5.9 | 3.5 | 6.8 | 2.1 | 0.98 | 6 500 | 5 000 |
| (USA and Canada) | 1200f-1.2E | 7.9 | 4.7 | 7.7 | 2.1 | 0.98 | 8 000 | 6 500 |
| | 1450f-1.3E | 9.5 | 5.7 | 8.5 | 2.1 | 0.98 | 9 000 | 7 000 |
| | 1650f-1.5E | 10.8 | 6.5 | 9.0 | 2.1 | 0.98 | 10 500 | 8 500 |
| | 1800f-1.6E | 11.8 | 7.1 | 9.3 | 2.4 | 0.98 | 11 500 | 9 000 |
| | 1950f-1.7E | 12.8 | 7.7 | 9.6 | 2.4 | 0.98 | 12 000 | 9 500 |
| | 2100f-1.8E | 13.8 | 8.3 | 10.1 | 2.4 | 0.98 | 13 000 | 10 500 |
| spruce-pine-fir | 900f-1.0E | 5.9 | 3.5 | 6.8 | 1.8 | 0.95 | 6 500 | 5 000 |
| (Canada) | 1200f-1.2E | 7.9 | 4.7 | 7.7 | 1.8 | 0.95 | 8 000 | 6 500 |
| | 1450f-1.3E | 9.5 | 5.7 | 8.5 | 1.8 | 0.95 | 9 000 | 7 000 |
| | 1650f-1.5E | 10.8 | 6.5 | 9.0 | 1.8 | 0.95 | 10 500 | 8 500 |
| | 1800f-1.6E | 11.8 | 7.1 | 9.3 | 2.1 | 0.95 | 11 500 | 9 000 |
| | 1950f-1.7E | 12.8 | 7.7 | 9.6 | 2.1 | 0.95 | 12 000 | 9 500 |
| | 2100f-1.8E | 13.8 | 8.3 | 10.1 | 2.1 | 0.95 | 13 000 | 10 500 |

NOTE These stresses should not be adjusted for width or depth of member.

[a] Grading rules applicable to timber of the following dimensions: 38 mm × 63 mm, 38 mm × 72 mm, 38 mm × 89 mm, 38 mm × 114 mm, 38 mm × 140 mm, 38 mm × 184 mm, 38 mm × 235 mm, 38 mm × 285 mm.

[b] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.

**Table 13 — Grade stresses for North American softwoods graded in accordance with North American MSR rules: for service classes 1 and 2** *(continued)*

| Standard name | Grade | Bending parallel to grain [a] | Tension parallel to grain | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [b] | | Mean | Minimum |
| | | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ | N/mm$^2$ |
| southern pine | 900f-1.0E | 5.9 | 3.5 | 6.8 | 2.7 | 1.37 | 6 500 | 5 000 |
| | 1200f-1.2E | 7.9 | 4.7 | 7.7 | 2.7 | 1.37 | 8 000 | 6 500 |
| | 1450f-1.3E | 9.5 | 5.7 | 8.5 | 2.7 | 1.37 | 9 000 | 7 000 |
| | 1650f-1.5E | 10.8 | 6.5 | 9.0 | 2.7 | 1.37 | 10 500 | 8 500 |
| | 1800f-1.6E | 11.8 | 7.1 | 9.3 | 3.1 | 1.37 | 11 500 | 9 000 |
| | 1950f-1.7E | 12.8 | 7.7 | 9.6 | 3.1 | 1.37 | 12 000 | 9 500 |
| | 2100f-1.8E | 13.8 | 8.3 | 10.1 | 3.1 | 1.37 | 13 000 | 10 500 |

NOTE These stresses should not be adjusted for width or depth of member.

[a] Grading rules applicable to timber of the following dimensions: 38 mm × 63 mm, 38 mm × 72 mm, 38 mm × 89 mm, 38 mm × 114 mm, 38 mm × 140 mm, 38 mm × 184 mm, 38 mm × 235 mm, 38 mm × 285 mm.

[b] When the specifications specifically prohibit wane at bearing areas, the SS grade compression perpendicular to the grain stress may be multiplied by 1.33 and used for all grades.

**Table 14 — Grade stresses for tropical hardwoods graded in accordance with BS 5756 rules: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain [a] | Tension parallel to grain [a] | Compression | | Shear parallel to grain | Modulus of elasticity | |
|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [b] | | Mean | Minimum |
| | | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² | N/mm² |
| balau | HS | 23.4 | 14.1 | 23.0 | 5.3 | 2.8 | 20 900 | 16 700 |
| ekki | HS | 25.0 | 15.0 | 24.6 | 5.6 | 3.0 | 18 500 | 15 500 |
| greenheart | HS | 26.1 | 15.6 | 23.7 | 5.9 | 2.6 | 21 600 | 18 000 |
| iroko | HS | 12.6 | 7.5 | 12.6 | 2.8 | 1.6 | 10 600 | 8 500 |
| jarrah | HS | 13.8 | 8.2 | 14.2 | 3.1 | 2.0 | 12 400 | 8 700 |
| kapur | HS | 18.1 | 10.9 | 18.0 | 4.1 | 1.9 | 19 200 | 15 800 |
| karri | HS | 17.1 | 10.3 | 15.2 | 3.9 | 1.7 | 17 800 | 13 500 |
| kempas | HS | 19.3 | 11.6 | 19.4 | 4.3 | 2.3 | 19 100 | 16 000 |
| keruing | HS | 16.2 | 9.7 | 16.0 | 3.6 | 1.7 | 19 300 | 16 100 |
| merbau | HS | 18.1 | 10.9 | 15.7 | 4.1 | 2.3 | 15 900 | 11 700 |
| opepe | HS | 17.0 | 10.2 | 17.6 | 3.8 | 2.1 | 14 500 | 11 300 |
| teak | HS | 13.7 | 8.2 | 13.4 | 3.1 | 1.7 | 10 700 | 7 400 |

[a] Stresses applicable to timber 300 mm deep (or wide); for other section sizes see **2.10.6** and **2.12.2**.
[b] When the specifications specifically prohibit wane at bearing areas, the HS grade compression perpendicular to the grain stress may be multiplied by 1.33.

**Table 15 — Grade and moduli of elasticity for temperate hardwoods graded in accordance with BS 5756 rules: for service classes 1 and 2**

| Standard name | Grade | Bending parallel to grain [a] | Tension parallel to grain [a] | Compression | | Shear parallel to grain | Modulus of elasticity | | Density | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Parallel to grain | Perpendicular to grain [b] | | Mean | Minimum | Characteristic, $\rho_k$ | Mean, $\rho_{mean}$ |
| | | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $N/mm^2$ | $kg/m^3$ | $kg/m^3$ |
| oak | TH1 | 9.6 | 5.8 | 9.3 | 3.0 | 2.0 | 12 500 | 8 500 | 569 | 680 |
| | TH2 | 7.8 | 4.7 | 8.4 | 3.0 | 2.0 | 10 500 | 7 000 | 598 | 704 |
| | THA | 12.6 | 7.6 | 10.5 | 3.0 | 2.0 | 13 500 | 10 500 | 595 | 713 |
| | THB | 9.1 | 5.5 | 9.0 | 3.0 | 2.0 | 12 000 | 7 500 | 584 | 692 |
| sweet chestnut | TH1 | 7.6 | 4.5 | 8.3 | 2.3 | 2.0 | 11 300 | 6 300 | 513 | 563 |

NOTE Because it is difficult to dry thick timber, timber that has a target thickness of 100 mm or more should be considered as service class 3 and the above strength properties multiplied by the factors in Table 16.

[a] Stresses applicable to timber 300 mm deep (or wide). For other section sizes, see **2.10.6**.
[b] When the specification specifically prohibits wane at the bearing areas, the TH1 grade perpendicular to the grain stress may be multiplied by 1.33 and this value used for TH2, THA and THB grades.

**Table 16 — Modification factor, $K_2$, by which stresses and moduli for service classes 1 and 2 should be multiplied to obtain stresses and moduli applicable to service class 3**

| Property | Value of $K_2$ |
|---|---|
| Bending parallel to grain | 0.8 |
| Tension parallel to grain | 0.8 |
| Compression parallel to grain | 0.6 |
| Compression perpendicular to grain | 0.6 |
| Shear parallel to grain | 0.9 |
| Mean and minimum modulus of elasticity | 0.8 |

## 2.7 Additional properties

In the absence of specific test data, values which are one-third of those for shear parallel to the grain (see Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15) should be used for tension perpendicular to the grain, torsional shear and rolling shear.

For modulus of elasticity perpendicular to the grain, a value of one-twentieth (i.e. 0.05) of the permissible modulus of elasticity (see Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15) should be used.

For shear modulus, a value of one-sixteenth (i.e. 0.062 5) of the permissible modulus of elasticity (see Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15) should be used.

Where the direction of the load is inclined to the grain at an angle $\alpha$, the permissible compression stress for the inclined surface should be calculated from the equation:

$$\sigma_{c,adm,\alpha} = \sigma_{c,adm,\parallel} - (\sigma_{c,adm,\parallel} - \sigma_{c,adm,\perp}) \sin \alpha$$

where

$\sigma_{c,adm,\parallel}$ and $\sigma_{c,adm,\perp}$ are the grade compression stresses, parallel and perpendicular to the grain, respectively, modified as appropriate for moisture content and/or duration of loading (see **2.6.2** and **2.8**).

## 2.8 Duration of loading

The stresses given in Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 apply to long-term loading. Table 17 gives the modification factor $K_3$ by which these should be multiplied for various durations of loading. When a modification factor, $K_3$, greater than unity is used in accordance with this clause, the design should be checked to ensure that the permissible stresses are not exceeded for any other condition of loading that might be relevant.

NOTE 1 The modification factor $K_3$ is applicable to all strength properties, but is not applicable to moduli of elasticity or to shear moduli.

NOTE 2 For domestic floors, the concentrated loading condition given in BS 6399-1 (i.e. 1.4 kN) may be superimposed on the dead load and both may be treated as of medium-term duration.

**Table 17 — Modification factor, $K_3$, for duration of loading**

| Duration of loading | Value of $K_3$ |
|---|---|
| Long-term (e.g. dead + permanent imposed [a]) | 1.00 |
| Medium-term (e.g. dead + snow, dead + temporary imposed) | 1.25 |
| Short-term (e.g. dead + imposed + wind [b], dead + imposed + snow + wind [b]) | 1.50 |
| Very short-term (e.g. dead + imposed + wind [c]) | 1.75 |

[a] For uniformly distributed imposed floor loads $K_3$ = 1.00 except for type C3 occupancy (see BS 6399-1:1996, Table 1) where for foot traffic on corridors, hallways, landings and stairs, $K_3$, may be taken as 1.5.

[b] For wind, short-term category applies to class C (15 s gust) as defined in CP3:Chapter V-2 or, where the largest diagonal dimension of the loaded area $a$, as defined in BS 6399-2, exceeds 50 m.

[c] For wind, very short-term category applies to classes A and B (3 s or 5 s gust) as defined in CP 3:Chapter V-2 or, where the largest diagonal dimension of the loaded area $a$, as defined in BS 6399-2, does not exceed 50 m.

## 2.9 Load-sharing systems

In a load-sharing system which consists of four or more members such as rafters, joists, trusses or wall studs, spaced a maximum of 610 mm centre to centre, and which has adequate provision for the lateral distribution of loads by means of purlins, binders, boarding, battens, etc., the following permissible stresses and moduli of elasticity appropriate to the strength class or species and grade should apply.

a) The appropriate grade stresses should be multiplied by the load sharing modification factor, $K_8$, which has a value of 1.1.

b) The mean modulus of elasticity should be used to calculate deflections and displacements under both dead and imposed load unless the imposed load is for an area intended for mechanical plant and equipment, or for storage, or for floors subject to vibrations, e.g. gymnasia and ballrooms, in which case the minimum modulus of elasticity should be used.

Special provisions for built-up beams, trimmer joists and lintels, and laminated beams, are given in **2.10.10**, **2.10.11** and section **3**, respectively.

The provisions of this clause do not extend to the calculation of modification factor, $K_{12}$, (given in Table 22 and Annex B) for load-sharing columns.

## 2.10 Flexural members

### 2.10.1 General

Permissible stresses for timber flexural members are governed by the particular conditions of service and loading as given in **2.6.2**, **2.8** and **2.9** and by the additional factors given in **2.10**. They should be taken as the product of the grade stress given in **2.6** and the appropriate modification factors.

### 2.10.2 Length and position of bearing

The grade stresses for compression perpendicular to the grain apply to bearings of any length at the ends of a member, and bearings 150 mm or more in length at any position. For bearings less than 150 mm long located 75 mm or more from the end of a member, as shown in Figure 1, the grade stress should be multiplied by the modification factor, $K_4$, given in Table 18.

NOTE 1 At any bearing on the side grain of timber, the permissible stress in compression perpendicular to the grain is dependent on the length and position of the bearing.

NOTE 2 No allowance need be made for the difference in intensity of the bearing stress due to rotation of a beam at the supports.

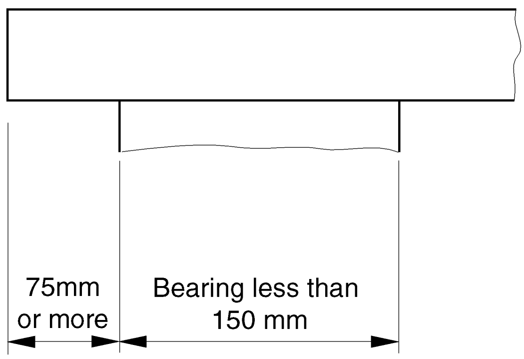



**Figure 1 — Position of end bearing**

**Table 18 — Modification factor, $K_4$, for bearing stress**

| Length of bearing [a] mm | Value of $K_4$ |
|---|---|
| 10 | 1.74 |
| 15 | 1.67 |
| 25 | 1.53 |
| 40 | 1.33 |
| 50 | 1.20 |
| 75 | 1.14 |
| 100 | 1.10 |
| 150 or more | 1.00 |

[a] Interpolation is permitted.

### 2.10.3 Effective span

The span of flexural members should be taken as the distance between the centres of bearings. Where members extend over bearings which are longer than is necessary, the spans may be measured between the centres of bearings of a length which should be adequate in accordance with BS 5268-2. Where this procedure is applied, due attention should be paid to the eccentricity of the load on the supporting structure.

### 2.10.4 Shear at notched ends

Square-cornered notches at the ends of a flexural member cause a stress concentration which should be allowed for as follows.

The shear strength should be calculated by using the effective depth, $h_e$, (see Figure 2) and a permissible stress equal to the grade stresses multiplied by the factor, $K_5$, where:

a) for a notch on the top edge [see Figure 2a)]

$$K_5 = \frac{h(h_e - a) + ah_e}{h_e^2} \text{ for } a \leq h_e$$

$$= 1.0 \text{ for } a > h_e;$$

b) for a notch on the underside [see Figure 2b)]

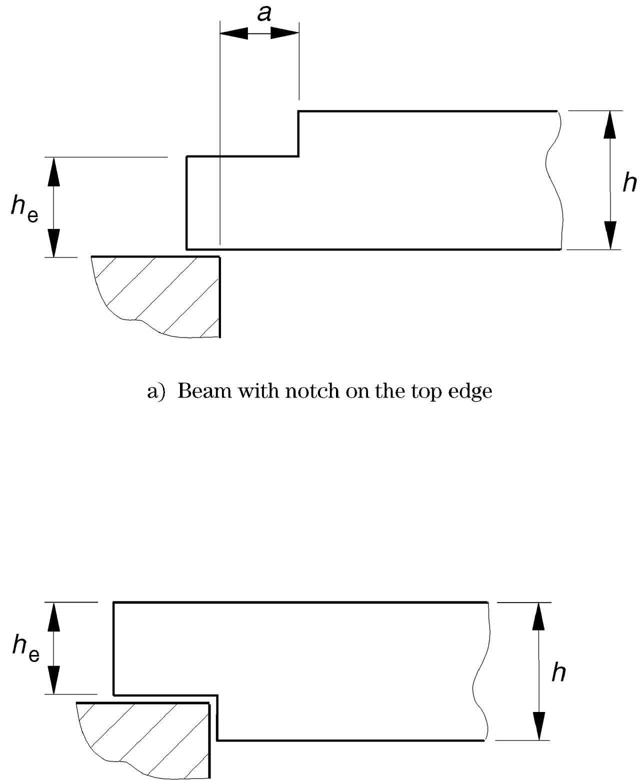
$$K_5 = \frac{h_e}{h};$$

where

$h$ is the total depth of the beam in millimetres (mm);

$a$ is as shown in Figure 2 in millimetres (mm).

The effective depth, $h_e$, should be not less than $0.5h$.




a) Beam with notch on the top edge

b) Beam with notch on the underside

**Figure 2 — Notched beams**

### 2.10.5 Form factor

Grade bending stresses apply to solid timber members of rectangular cross-section. For other shapes of cross-section the grade bending stresses should be multiplied by the modification factor, $K_6$, where

$K_6$ = 1.18 for solid circular sections; and

$K_6$ = 1.41 for solid square sections loaded on a diagonal.

### 2.10.6 Total depth of beam

The grade bending stresses given in Table 8 apply to material assigned to a strength class and having a depth, $h$, of 300 mm.

The grade bending stresses given in Table 10, Table 11, Table 12, Table 13 and Table 14 apply as appropriate to:

a) solid timber graded in accordance with BS 4978, BS 5756 or BS EN 519 and having a depth, $h$, of 300 mm;

b) solid timber graded in accordance with the NLGA or NGRDL structural light framing, light framing or stud rules and having a depth, $h$, of 300 mm;

c) solid timber graded in accordance with the North American MSR rules having the particular depth quoted;

d) solid timber graded in accordance with the NLGA or NGRDL joist and plank rules and having a depth, $h$, of 300 mm;

e) all thicknesses of laminations graded in accordance with BS 4978 or BS 5756.

For other depths of beams assigned to a strength class or graded in accordance with BS 4978, BS 5756, BS EN 519 or NLGA and NGRDL joist and plank, structural light framing, light framing and stud rules, the grade bending stresses should be multiplied by the depth modification factor, $K_7$, where:

$K_7 = 1.17$ for solid timber beams having $h \leqslant 72$ mm;

$K_7 = (300/h)^{0.11}$ for solid and glued laminated beams having 72 mm < $h \leqslant 300$ mm;

$K_7 = 0.81 \dfrac{(h^2 + 92\ 300)}{(h^2 + 56\ 800)}$ for solid and glued laminated beams having $h > 300$ mm.

### 2.10.7 Deflection and stiffness

The dimensions of flexural members should be such as to restrict deflection within limits appropriate to the type of structure, having regard to the possibility of damage to surfacing materials, ceilings, partitions and finishings, and to the functional needs as well as aesthetic requirements.

In addition to the deflection due to bending, the shear deflection may be significant and should be taken into account.

For most general purposes, this recommendation may be assumed to be satisfied if the deflection of the member when fully loaded does not exceed 0.003 of the span. For domestic floor joists, the deflection under full load should not exceed 0.003 times the span or 14 mm, whichever is the lesser. More comprehensive procedures covering various load types and duration are given in Annex K.

NOTE The 14 mm deflection limitation is to avoid undue vibration under moving or impact loading.

Subject to consideration being given to the effect of excessive deformation, members may be precambered to account for the deflection under full dead or permanent load, and in this case the deflection under live or intermittent load should not exceed 0.003 of the span.

The deflections of solid timber members acting alone should be calculated using the minimum modulus of elasticity for the strength class or species and grade.

The deflections of load-sharing systems, built-up beams, trimmer joists and lintels should be calculated using the provisions of **2.9**, **2.10.10** and **2.10.11**, respectively.

### 2.10.8 Lateral support

The depth to breadth ratio of solid and laminated beams of rectangular section should be checked to ensure that there is no risk of buckling under design load. Alternatively, the recommendations of Table 19 should be followed.

**Table 19 — Maximum depth to breadth ratios (solid and laminated members)**

| Degree of lateral support | Maximum depth to breadth ratio |
|---|---|
| No lateral support | 2 |
| Ends held in position | 3 |
| Ends held in position and member held in line as by purlins or tie rods at centres not more than 30 times breadth of the member | 4 |
| Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists | 5 |
| Ends held in position and compression edge held in line, as by direct connection of sheathing, deck or joists, together with adequate bridging or blocking spaced at intervals not exceeding six times the depth | 6 |
| Ends held in position and both edges held firmly in line | 7 |



### 2.10.9 Notched or drilled beams

In calculating the strength of notched or drilled beams, allowance should be made for the notches or holes, the effective depth being taken as the minimum depth of the net section.

The effect of notches and holes need not be calculated in simply supported floor and roof-joists not more than 250 mm deep where:

a) notches not exceeding 0.125 of the depth of a joist are located between 0.07 and 0.25 of the span from the support; and

b) holes drilled at the neutral axis with diameter not exceeding 0.25 of the depth of a joist and not less than three diameters (centre to centre) apart are located between 0.25 and 0.4 of the span from the support.

### 2.10.10 Built-up beams

Built-up beams should be checked to ensure that there is no risk of buckling under design load.

In built-up members with thin webs, web stiffeners should be provided to ensure the strength and stability of the member at all points of concentrated load, or elsewhere as necessary.

The lateral stability should be determined by calculation, or by consideration of the compression flange as a column which tends to deflect sideways between points of lateral support, or in accordance with one of the following:

a) if the ratio of the second moment of area of the cross-section about the neutral axis to the second moment of area about the axis perpendicular to the neutral axis does not exceed 5 to 1, no lateral support is required;

b) if the ratio of the second moments of area is between 5:1 and 10:1, the ends of the beam should be held in position at the bottom flange at the supports;

c) if the ratio of the second moments of area is between 10:1 and 20:1, the beam should be held in line at the ends;

d) if the ratio of the second moments of area is between 20:1 and 30:1, one edge should be held in line;

e) if the ratio of the second moments of area is between 30:1 and 40:1, the beam should be restrained by bridging or other bracing at intervals of not more than 2.4 m;

f) if the ratio of the second moments of area is greater than 40:1, the compression flanges should be fully restrained.

The modification factors, $K_{27}$, $K_{28}$ and $K_{29}$, given in Table 25 may be used for the flanges of glued built-up beams such as box and I-beams. The number of pieces of timber in each flange should be taken as the number of laminations, irrespective of their orientation, to determine the value of the stress modification factors ($K_{27}$, $K_{28}$ and $K_{29}$) for that flange. The total number of pieces of timber in both flanges should be taken as the number of laminations necessary to determine the value of $K_{28}$ that is to be applied to the minimum modulus of elasticity for deflection calculations.

In addition to the deflection of a built-up beam due to bending, the shear deflection may be significant and should be taken into account.

### 2.10.11 Trimmer joists and lintels

For trimmer joists and lintels comprising two or more pieces connected together in parallel and acting together to support the loads, the grade stresses in bending and shear parallel to the grain, and in compression perpendicular to the grain should be multiplied by the load-sharing stress modification factor, $K_8$, which has a value of 1.1.

The minimum modulus of elasticity modified by the factor, $K_9$, (see Table 20) should be used for calculation of deflections.

**Table 20 — Modification factor, $K_9$, used to modify the minimum modulus of elasticity for trimmer joists and lintels**

| Number of pieces | Value of $K_9$ | |
|---|---|---|
| | Softwoods | Hardwoods |
| 1 | 1.00 | 1.00 |
| 2 | 1.14 | 1.06 |
| 3 | 1.21 | 1.08 |
| 4 or more | 1.24 | 1.10 |

## 2.11 Compression members

### 2.11.1 General

The limitations on bow in most strength grading rules are inadequate for the selection of material for columns. Particular attention should therefore be paid to the straightness of columns, for example, by limiting bow or spring to approximately 1/300 of the length.

Permissible stresses for timber members subjected to compression in the direction of the grain are governed by the particular conditions of service and loading given in **2.6.2**, **2.8** and **2.9**, and by the additional factors given in **2.11**.

### 2.11.2 Size factors

The grade compression stresses given in Table 8, Table 9, Table 10, Table 11, Table 12, Table 13 and Table 14 apply to all solid timber members and laminations graded in accordance with BS 4978, BS 5756 or BS EN 519.

### 2.11.3 Effective length

The effective length of a compression member should be derived from either:

a) Table 21 for the particular end conditions; or

b) the deflected form of the compression member as affected by any restraint and/or fixing moment(s), the effective length being the distance between adjacent points of zero bending between which the member is in single curvature.

**Table 21 — Effective length of compression members**

| End condition | $L_e/L$ [a] |
|---|---|
| Restrained at both ends in position and in direction | 0.7 |
| Restrained at both ends in position and one end in direction | 0.85 |
| Restrained at both ends in position but not in direction | 1.0 |
| Restrained at one end in position and in direction and at the other end in direction but not in position | 1.5 |
| Restrained at one end in position and in direction and free at the other end | 2.0 |

[a] $L_e$ is the effective length and $L$ is the actual length.

### 2.11.4 Slenderness ratio

The slenderness ratio of compression members should be calculated as the effective length, $L_e$, divided by the radius of gyration, $i$.

The slenderness ratio should not exceed 180 for:

a) any compression member carrying dead and imposed loads other than loads resulting from wind;

b) any compression member, however loaded, which by its deformation will adversely affect the stress in another member carrying dead and imposed loads other than wind.



The slenderness ratio should not exceed 250 for:

c) any member normally subject to tension or combined tension and bending arising from dead and imposed loads, but subject to a reversal of axial stress solely from the effect of wind;

d) any compression member carrying self weight and wind loads only (e.g. wind bracing).

**2.11.5 Members subject to axial compression (without bending)**

For compression members with slenderness ratios of less than 5, without undue eccentricity of loading, the permissible stress should be taken as the grade compression parallel to the grain stress modified as appropriate for moisture content, duration of loading and load sharing (see **2.6**, **2.8**, **2.9** and **2.11.2**).

For compression members with slenderness ratios equal to or greater than 5, the permissible stress should be calculated as the product of the grade compression parallel to the grain stress, modified as appropriate for moisture content, duration of loading and load sharing, and the modification factor, $K_{12}$, given in Table 22, or calculated using the equation given in Annex B.

The value of modulus of elasticity used to enter Table 22 or the equation in Annex B for both compression members acting alone and compression members in load-sharing systems should be the minimum modulus of elasticity. For members comprising two or more pieces connected together in parallel and acting together to support the loads, the minimum modulus of elasticity should be modified by $K_9$ (see Table 20) or $K_{28}$ (see Table 25). For horizontally laminated members, the modified mean modulus of elasticity should be used (see **3.2** and **3.6**). The compression parallel to the grain stress, $\sigma_c$, used to enter Table 22 or the equation in Annex B should be the grade stress modified only for moisture content, duration of loading, and size where applicable.

When checking that the permissible stresses of a compression member are not exceeded, consideration should be given to all relevant loading conditions, since in the expression $E/\sigma_{c,\parallel}$, used to enter Table 22 or the equation in Annex B, the modulus of elasticity is constant for all load durations, whereas the compression stress should be modified for duration of loading (see **2.8**).

**2.11.6 Members subject to axial compression and bending**

A member restrained at both ends, in position but not in direction, and subject to bending and axial compression should be so proportioned that:

$$\frac{\sigma_{m,a,\parallel}}{\sigma_{m,adm,\parallel}\left(1-\dfrac{1.5\sigma_{c,a,\parallel}}{\sigma_e}\times K_{12}\right)}+\frac{\sigma_{c,a,\parallel}}{\sigma_{c,adm,\parallel}}\leq 1$$

where

$\sigma_{m,a,\parallel}$ is the applied bending stress;

$\sigma_{m,adm,\parallel}$ is the permissible bending stress;

$\sigma_{c,a,\parallel}$ is the applied compression stress;

$\sigma_{c,adm,\parallel}$ is the permissible compression stress (including $K_{12}$);

$\sigma_e$ is the Euler critical stress $\pi^2E/(L_c/i)^2$, where $E$ is the modulus of elasticity given in **2.11.5**.

The effective length of a member subject to axial compression and bending should be that given in **2.11.3**b).

For members in load-sharing systems (see **2.9**), the permissible bending stress, $\sigma_{m,adm,\parallel}$, and the permissible compression stress, $\sigma_{c,adm,\parallel}$, should be multiplied by the load-sharing stress modification factor, $K_8$, which has a value of 1.1, or $K_{27}$ or $K_{28}$, as applicable.

The dimensions of compression members subject to bending should be such as to restrict deflection within limits appropriate to the type of structure.

**Table 22 — Modification factor, $K_{12}$, for compression members**

| $E/\sigma_{c,\parallel}$ | Value of $K_{12}$ | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Values of slenderness ratio $\lambda$ (= $L_e/i$) | | | | | | | | | | | | | | | | | | | |
| | <5 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 250 |
| | Equivalent $L_e/b$ (for rectangular sections) | | | | | | | | | | | | | | | | | | | |
| | <1.4 | 1.4 | 2.9 | 5.8 | 8.7 | 11.6 | 14.5 | 17.3 | 20.2 | 23.1 | 26.0 | 28.9 | 34.7 | 40.5 | 46.2 | 52.0 | 57.8 | 63.6 | 69.4 | 72.3 |
| 400 | 1.000 | 0.975 | 0.951 | 0.896 | 0.827 | 0.735 | 0.621 | 0.506 | 0.408 | 0.330 | 0.271 | 0.225 | 0.162 | 0.121 | 0.094 | 0.075 | 0.061 | 0.051 | 0.043 | 0.040 |
| 500 | 1.000 | 0.975 | 0.951 | 0.899 | 0.837 | 0.759 | 0.664 | 0.562 | 0.466 | 0.385 | 0.320 | 0.269 | 0.195 | 0.148 | 0.115 | 0.092 | 0.076 | 0.063 | 0.053 | 0.049 |
| 600 | 1.000 | 0.975 | 0.951 | 0.901 | 0.843 | 0.774 | 0.692 | 0.601 | 0.511 | 0.430 | 0.363 | 0.307 | 0.226 | 0.172 | 0.135 | 0.109 | 0.089 | 0.074 | 0.063 | 0.058 |
| 700 | 1.000 | 0.975 | 0.951 | 0.902 | 0.848 | 0.784 | 0.711 | 0.629 | 0.545 | 0.467 | 0.399 | 0.341 | 0.254 | 0.195 | 0.154 | 0.124 | 0.102 | 0.085 | 0.072 | 0.067 |
| 800 | 1.000 | 0.975 | 0.952 | 0.903 | 0.851 | 0.792 | 0.724 | 0.649 | 0.572 | 0.497 | 0.430 | 0.371 | 0.280 | 0.217 | 0.172 | 0.139 | 0.115 | 0.096 | 0.082 | 0.076 |
| 900 | 1.000 | 0.976 | 0.952 | 0.904 | 0.853 | 0.797 | 0.734 | 0.665 | 0.593 | 0.522 | 0.456 | 0.397 | 0.304 | 0.237 | 0.188 | 0.153 | 0.127 | 0.106 | 0.091 | 0.084 |
| 1 000 | 1.000 | 0.976 | 0.952 | 0.904 | 0.855 | 0.801 | 0.742 | 0.677 | 0.609 | 0.542 | 0.478 | 0.420 | 0.325 | 0.255 | 0.204 | 0.167 | 0.138 | 0.116 | 0.099 | 0.092 |
| 1 100 | 1.000 | 0.976 | 0.952 | 0.905 | 0.856 | 0.804 | 0.748 | 0.687 | 0.623 | 0.559 | 0.497 | 0.440 | 0.344 | 0.272 | 0.219 | 0.179 | 0.149 | 0.126 | 0.107 | 0.100 |
| 1 200 | 1.000 | 0.976 | 0.952 | 0.905 | 0.857 | 0.807 | 0.753 | 0.695 | 0.634 | 0.573 | 0.513 | 0.457 | 0.362 | 0.288 | 0.233 | 0.192 | 0.160 | 0.135 | 0.116 | 0.107 |
| 1 300 | 1.000 | 0.976 | 0.952 | 0.905 | 0.858 | 0.809 | 0.757 | 0.701 | 0.643 | 0.584 | 0.527 | 0.472 | 0.378 | 0.303 | 0.247 | 0.203 | 0.170 | 0.144 | 0.123 | 0.115 |
| 1 400 | 1.000 | 0.976 | 0.952 | 0.906 | 0.859 | 0.811 | 0.760 | 0.707 | 0.651 | 0.595 | 0.539 | 0.486 | 0.392 | 0.317 | 0.259 | 0.214 | 0.180 | 0.153 | 0.131 | 0.122 |
| 1 500 | 1.000 | 0.976 | 0.952 | 0.906 | 0.860 | 0.813 | 0.763 | 0.712 | 0.658 | 0.603 | 0.550 | 0.498 | 0.405 | 0.330 | 0.271 | 0.225 | 0.189 | 0.161 | 0.138 | 0.129 |
| 1 600 | 1.000 | 0.976 | 0.952 | 0.906 | 0.861 | 0.814 | 0.766 | 0.716 | 0.664 | 0.611 | 0.559 | 0.508 | 0.417 | 0.342 | 0.282 | 0.235 | 0.198 | 0.169 | 0.145 | 0.135 |
| 1 700 | 1.000 | 0.976 | 0.952 | 0.906 | 0.861 | 0.815 | 0.768 | 0.719 | 0.669 | 0.618 | 0.567 | 0.518 | 0.428 | 0.353 | 0.292 | 0.245 | 0.207 | 0.177 | 0.152 | 0.142 |
| 1 800 | 1.000 | 0.976 | 0.952 | 0.906 | 0.862 | 0.816 | 0.770 | 0.722 | 0.673 | 0.624 | 0.574 | 0.526 | 0.438 | 0.363 | 0.302 | 0.254 | 0.215 | 0.184 | 0.159 | 0.148 |
| 1 900 | 1.000 | 0.976 | 0.952 | 0.907 | 0.862 | 0.817 | 0.772 | 0.725 | 0.677 | 0.629 | 0.581 | 0.534 | 0.447 | 0.373 | 0.312 | 0.262 | 0.223 | 0.191 | 0.165 | 0.154 |
| 2 000 | 1.000 | 0.976 | 0.952 | 0.907 | 0.863 | 0.818 | 0.773 | 0.728 | 0.681 | 0.634 | 0.587 | 0.541 | 0.455 | 0.382 | 0.320 | 0.271 | 0.230 | 0.198 | 0.172 | 0.160 |

### 2.11.7 Notching and drilling

When it is necessary to notch or drill a compression member, allowance for the notches or holes should be made in the design.

NOTE The effect of holes need not be calculated where circular holes with diameters not exceeding 25 % of the width of the member are positioned on the neutral axis at between 25 % and 40 % of the actual length from the end or from a support.

### 2.11.8 Spaced columns

A spaced column is composed of two or more equal shafts, spaced apart by end and intermediate packing blocks, which are glued, bolted, screwed, nailed or connectored in position in accordance with **2.11.9** and section **6**.

The clear space between individual shafts (in which packings are inserted), should not be greater than three times the thickness of the shaft, measured in the same plane.

### 2.11.9 Packs for spaced columns

#### 2.11.9.1 *End packs*

**2.11.9.1.1** *Mechanical connections*

End packings should be of a length sufficient to accommodate the nails, screws or connectors required to transmit, between the abutting face of the packing and one adjacent shaft, a shear force equal to:

$$\frac{1.3Ab\sigma_{c,a,\parallel}}{na}$$

where

| | |
|---|---|
| $A$ | is the total section area of the column; |
| $b$ | is the thickness of the shaft; |
| $\sigma_{c,a,\parallel}$ | is the applied compression stress; |
| $n$ | is the number of shafts; |
| $a$ | is the distance between centres of adjacent shafts. |

In addition, the length of the packing measured along the axis of the column should be not less than six times the thickness of the individual shaft.

**2.11.9.1.2** *Glued connections*

End packings should be of a length sufficient to provide the glue area required to transmit a shear force between the abutting face of the packing and one adjacent shaft, calculated as given for end packings mechanically connected. In addition, the length of the packing measured along the axis of the column should be not less than six times the thickness of the individual shaft.

Shop fabrication of spaced columns employing glued packings may be carried out using suitable clamps, or clamping pressure may be obtained by screwing or bolting between column shafts and the packings. In the latter case, at least four screws or bolts should be provided per packing and these should be so spaced as to obtain an even pressure over the area of the packing.

#### 2.11.9.2 *Intermediate packs*

Intermediate packings should be not less than 230 mm long, measured along the axis of the column, and should be designed to transmit, between the abutting face of the packing and one adjacent shaft, a shear force of not less than one half of the corresponding shear force for the end packing (see **2.11.9.1.1**).

Where the length of the column does not exceed 30 times the thickness of the shaft, only one intermediate packing need be provided. In any event, sufficient packings should be provided to ensure that the greater slenderness ratio ($L_e/i$) of the local portion of an individual shaft between packings is limited to either 70, or to 0.7 times the slenderness ratio of the whole column, whichever is the lesser. For the purpose of calculating the slenderness ratio of the local portion of an individual shaft, the effective length, $L_e$, should be taken as the length between the centroids of the groups of mechanical connectors or glue areas in adjacent packings.

### 2.11.10 Permissible stresses for spaced columns

For the purpose of calculating the permissible stress on a spaced column, the radii of gyration should be calculated about the axes X–X and Y–Y as indicated in Figure 3.

The effective length of the column, for buckling about the axes X–X or Y–Y should be assessed in accordance with Table 21.

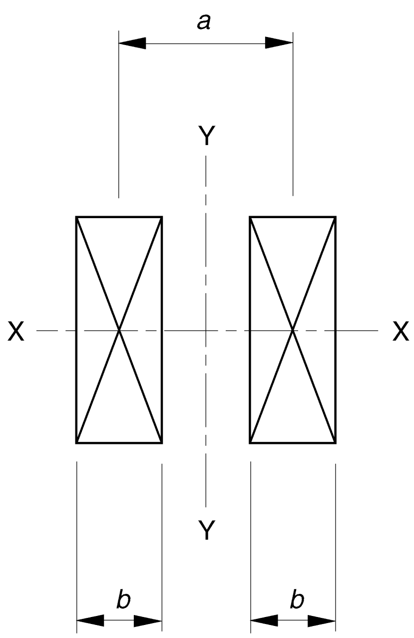



**Figure 3 — Axes in spaced columns**

The permissible load should then be taken as the least of the following:

a) that for a solid column (whose area is that of the area of the timber) bending about axis X–X;

b) that for a solid column whose area is that of one member of the built-up column, and whose effective length is equal to the spacing of the packing pieces, multiplied by the number of shafts;

c) that for a column bending about the axis Y–Y whose geometrical properties of cross-section are those of the built-up column, but whose effective length is multiplied by the modification factor, $K_{13}$, given in Table 23.

**Table 23 — Modification factor, $K_{13}$, for the effective length of spaced columns**

| Method of connection | Value of $K_{13}$ | | | |
|---|---|---|---|---|
| | Ratio of space to thickness of the thinner member | | | |
| | 0 | 1 | 2 | 3 |
| Nailed | 1.8 | 2.6 | 3.1 | 3.5 |
| Screwed or bolted | 1.7 | 2.4 | 2.8 | 3.1 |
| Connectored | 1.4 | 1.8 | 2.2 | 2.4 |
| Glued | 1.1 | 1.1 | 1.3 | 1.4 |

**2.11.11 Compression members in triangulated frameworks**

Compression members in triangulated frameworks such as trusses and girders (but excluding trussed rafters designed in accordance with BS 5268-3) should be designed in accordance with the previous clauses subject to the following.

a) With continuous compression members, the effective length for the purpose of determining the slenderness ratio may be taken as between 0.85 and 1.0 (depending upon the degree of fixity and the distribution of load between node points) times the distance between the node points of the framework for buckling in the plane of the framework and times the actual distance between effective lateral restraints for buckling perpendicular to the plane of the framework. With roof trusses, purlins or tiling battens may be taken as providing effective lateral restraints, provided they are adequately fastened to the top chord and are carried back to effective bracing or other support. With roofs employing rafters adequately fastened to a continuous restraint, e.g. a boarded covering, it can be taken that effective lateral restraint is provided along the whole length of the rafter.

b) With non-continuous compression members, such as web members in a framework, the effective length for buckling depends on the type of connection at the ends of the members and may be calculated using the appropriate end fixity (see Table 21).

Where a single bolt or connector at the end of a compression member permits rotation of the member, its effective length should be taken as the actual distance between bolts or connectors.

Where a web member fastened by glued gusset plates is partially restrained at both ends in position and direction, the effective lengths for buckling in and out of the plane of the truss should be taken as 0.9 times the actual distance between the points of intersection of the lines passing through the centroids of the members connected.

c) The recommendations in **2.11.9.1.1** with regard to end packings and **2.11.9.2** with regard to intermediate packings do not apply to spaced compression members in triangulated frameworks. Intermediate packings should be not less than 200 mm long and should be fixed in such a manner as to transmit a tensile force parallel to axis X–X, between the individual members, of not less than 2.5 % of the total axial force in the spaced compression member.

## 2.12 Tension members

**2.12.1 General**

Permissible stresses for timber tension members are governed by the particular conditions of service and loading as given in **2.6.2**, **2.8** and **2.9** and by the additional factors given in this clause. They should be determined as the product of the grade stress and the appropriate modification factors.

**2.12.2 Width factor**

The grade tension stresses given in Table 8 and Table 9 apply to material assigned to a strength class and having a width (i.e. the greater transverse dimension), $h$, of 300 mm.

The grade tension stresses given in Table 10, Table 11, Table 12, Table 13 and Table 14 apply, as appropriate, to:

a) solid timber graded in accordance with BS 4978, BS 5756 or BS EN 519 and having a width, $h$, of 300 mm;

b) solid timber graded to the NLGA or NGRDL joist and plank, structural light framing, light framing and stud rules and having a width, $h$, of 300 mm;

c) solid timber graded to the North American MSR rules having the particular width quoted;

d) laminations graded in accordance with BS 4978 or BS 5756.

For other widths of members assigned to a strength class or graded to BS 4978, BS 5756, BS EN 519, NLGA or NGRDL joist and plank, structural light framing, light framing and stud rules, the grade tension stresses should be multiplied by the width modification factor, $K_{14}$, where

$K_{14}$ = 1.17 for solid timber members having a width of 72 mm or less; and

$K_{14}$ = $(300/h)^{0.11}$ for solid and glued laminated members having a width greater than 72 mm.

**2.12.3 Members subject to axial tension and bending**

Members subject to both bending and axial tension should be proportioned so that:

$$\frac{\sigma_{m,a,\parallel}}{\sigma_{m,adm,\parallel}} + \frac{\sigma_{t,a,\parallel}}{\sigma_{t,adm,\parallel}} \leq 1$$

where

$\sigma_{m,a,\parallel}$ is the applied bending stress;

$\sigma_{m,adm,\parallel}$ is the permissible bending stress;

$\sigma_{t,a,\parallel}$ is the applied tension stress;

$\sigma_{t,adm,\parallel}$ is the permissible tension stress.

# Section 3. Glued laminated timber

## 3.1 General

Glued laminated timber should be manufactured in accordance with BS EN 386 and **3.4**.

All timber used for laminated softwood members should be strength graded visually or mechanically in accordance with BS EN 518 or BS EN 519, respectively, and the additional recommendations for wane, etc. given in the National annex of BS EN 386:1995. All timber used for laminated hardwood members, should be strength graded in accordance with BS 5756.

NOTE 1 The stresses given in BS 5268-2 apply only to timber graded in accordance with BS EN 518, BS EN 519 and BS 5756. Because these standards are primarily for solid structural timber, manufacturers of glued laminated timber may need to specify overriding requirements for wane, fissures and distortion.

NOTE 2 Glulam strength properties may be determined from the strength class properties given in Table 8 and Table 9 and the assignments of many grades and species to those classes are given in Table 2, Table 3, Table 4, Table 6 and Table 7. BS EN 1912 assigns other grades, which conform to BS EN 518, to the strength classes. Glulam designed and manufactured in accordance with the recommendations given in BS 5268-2 but using grades in accordance with BS EN 1912, is acceptable.

## 3.2 Grade stresses for horizontally glued laminated members

The grade stresses for a horizontally glued laminated softwood or hardwood member should be taken as the products of the strength class stresses given in Table 8 and Table 9 for the relevant grade and species, and the modification factors from Table 24 appropriate to the strength class of timber used for the laminations. Alternatively, the grade stresses should be taken as the products of the stresses for the relevant strength grade and species given in Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 and the modification factors from Table 24 appropriate for the strength class to which that grade and species are assigned in Table 2, Table 3, Table 4, Table 5, Table 6 and Table 7. It should be noted that the size factors, $K_7$ and $K_{14}$, should not be applied to the laminate strengths, only to the glulam strengths.

For tension perpendicular to grain and torsional shear, permissible stresses should be calculated in accordance with **2.7**, and factors $K_{19}$ and $K_{27}$ should be disregarded.

Table 24 applies to members horizontally laminated from one strength class. Members may be horizontally laminated from two strength classes, provided that the strength classes are not more than three classes apart in Table 8 and Table 9 (i.e. C24 and C16 may be horizontally laminated, but C24 and C14 may not), and the members are fabricated so that not less than 25 % of the depth at both the top and bottom of the member is of the superior strength class. For such members the grade stresses should be taken as the products of the strength class stresses given in Table 8 and Table 9 for the superior laminations, and the modification factors from Table 24.

For bending, tension and compression parallel to grain grade stresses, these values should then be multiplied by 0.95.

The modification factors given in Table 24 apply to members having four or more laminations, all of similar thickness.

## 3.3 Grade stresses for vertically glued laminated beams

Permissible stresses for vertically glued laminated beams are governed by the particular conditions of service and loading given in **2.6.2**, **2.8** and **2.9** and by the modification factors, $K_{27}$, $K_{28}$ and $K_{29}$, given in Table 25 appropriate to the number of laminations. It should be noted that the size factors, $K_7$ and $K_{14}$, should not be applied to the laminate strengths, only to the glulam strengths.

The modification factors given in Table 25 apply to the mechanical properties given in Table 8 and Table 9.

For tension perpendicular to grain and torsional shear, permissible stresses should be calculated according to **2.7** and factor $K_{27}$ should be disregarded.

## 3.4 Glued end joints in glued laminated timber

Finger joints should have characteristic bending strengths of not less than the characteristic bending strength of the strength class for the lamination (see Table 101), when tested in accordance with BS EN 385.

Alternatively, end joints in laminations should have bending efficiency ratings (regardless of the type of loading) equal to or greater than the values given in Table 102. Where end joints with a lower efficiency rating than is required for the strength class are used, the maximum bending, tension or compression parallel to the grain stress to which a glued end joint in any individual lamination is subjected, should not exceed the value obtained by multiplying the stress for the strength class given in Table 8 and Table 9 by the efficiency rating for the joint (see Annex C), by the appropriate modification factors for size of member, moisture content and duration of loading, and also by modification factor, $K_{30}$, $K_{31}$ or $K_{32}$, from Table 26, as appropriate to the type of loading.

For a vertically glued laminated beam, glued end joints should have an efficiency of not less than that required for the strength class or species and grade of timber (see Annex C and Table 102) unless the permissible stress is reduced accordingly.

NOTE It can be assumed that the presence of finger joints or plain scarf joints in a lamination does not affect its modulus of elasticity. The full cross-section of jointed laminations may be used for strength and stiffness calculations.

**Table 24 — Modification factors, $K_{15}$, $K_{16}$, $K_{17}$, $K_{18}$, $K_{19}$ and $K_{20}$, for single grade glued laminated members and horizontally glued laminated beams**

| Strength classes | Number of laminations [a] | Bending parallel to grain $K_{15}$ | Tension parallel to grain $K_{16}$ | Compression parallel to grain $K_{17}$ | Compression perpendicular to grain $K_{18}$ [b] | Shear parallel to grain $K_{19}$ | Modulus of elasticity $K_{20}$ [c] |
|---|---|---|---|---|---|---|---|
| C27, C30, D50, D60, D70 | 4 or more | 1.39 | 1.39 | 1.11 | 1.49 | 1.49 | 1.03 |
| C22, C24, | 4 | 1.26 | 1.26 | 1.04 | 1.55 | 2.34 | 1.07 |
| D35, D40 | 5 | 1.34 | 1.34 | | | | |
| | 7 | 1.39 | 1.39 | | | | |
| | 10 | 1.43 | 1.43 | | | | |
| | 15 | 1.48 | 1.48 | | | | |
| | 20 or more | 1.52 | 1.52 | | | | |
| C16, | 4 | 1.05 | 1.05 | 1.07 | 1.69 | 2.73 | 1.17 |
| C18, D30 | 5 | 1.16 | 1.16 | | | | |
| | 7 | 1.29 | 1.29 | | | | |
| | 10 | 1.39 | 1.39 | | | | |
| | 15 | 1.49 | 1.49 | | | | |
| | 20 or more | 1.57 | 1.57 | | | | |

[a] Interpolation is permitted for intermediate numbers of laminations.
[b] $K_{18}$ should be applied to the lower value given in Table 8 or Table 9 for compression perpendicular to grain.
[c] $K_{20}$ should be applied to the mean value of modulus of elasticity.

**Table 25 — Modification factors, $K_{27}$, $K_{28}$ and $K_{29}$, for vertically glued laminated members**

<table>
<tr><th rowspan="2">Number of laminations</th><th colspan="2">Bending, tension and shear parallel to grain $K_{27}$</th><th colspan="2">Modulus of elasticity, compression parallel to grain $K_{28}$ [a]</th><th>Compression perpendicular to grain $K_{29}$ [b]</th></tr>
<tr><th>Softwoods</th><th>Hardwoods</th><th>Softwoods</th><th>Hardwoods</th><th>Softwoods and hardwoods</th></tr>
<tr><td>2<br>3<br>4</td><td>1.11<br>1.16<br>1.19</td><td>1.06<br>1.08<br>1.10</td><td>1.14<br>1.21<br>1.24</td><td>1.06<br>1.08<br>1.10</td><td rowspan="5">1.10</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>5<br>6<br>7</td><td>1.21<br>1.23<br>1.24</td><td>1.11<br>1.12<br>1.12</td><td>1.27<br>1.29<br>1.30</td><td>1.11<br>1.12<br>1.12</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>8 or more</td><td>1.25</td><td>1.13</td><td>1.32</td><td>1.13</td></tr>
<tr><td colspan="6">[a] When applied to the value of the modulus of elasticity, $E$, $K_{28}$ is applicable to the minimum value of $E$.<br>[b] If no wane is present, $K_{29}$ should have the value 1.33 and, regardless of the grade of timber used, should be applied to the SS or HS grade stress for the species.</td></tr>
</table>

**Table 26 — Modification factors, $K_{30}$, $K_{31}$ and $K_{32}$, for individually designed glued end joints in horizontally glued laminated members**

| Timber | Bending parallel to grain $K_{30}$ | Tension parallel to grain $K_{31}$ | Compression parallel to grain $K_{32}$ |
|---|---|---|---|
| Softwood | 1.63 | 1.63 | 1.43 |
| Hardwood | 1.32 | 1.32 | 1.42 |

If other types of end joint are used, either the contribution of the laminations in which they occur should be omitted when calculating the strength and stiffness properties of the section, or their suitability for use should be established by test.

## 3.5 Glued laminated flexural members

### 3.5.1 General

The permissible stresses for glued laminated timber flexural members are governed by the particular conditions of service and loading as given in **2.6.2**, **2.8** and **2.9** by the modification factors for flexural timber members given in **2.10** and by the additional factors given in **3.5**.

In addition to the deflection due to bending, the shear deflection may be significant and should be taken into account.

### 3.5.2 Camber

Subject to due regard being paid to the effect of deformation, members may be pre-cambered to offset the deflection under dead or permanent loads, and in this case the deflection under live or intermittent imposed load should not exceed 0.003 of the span.

### 3.5.3 Curved glued laminated beams

#### 3.5.3.1 *General*

For curved glued laminated beams with constant rectangular cross-section (see Figure 4) the ratio of the radius of curvature, $r$, to the lamination thickness, $t$, should be greater than the mean modulus of elasticity, in newtons per square millimetre (N/mm$^2$), for the strength class divided by 70, for both hardwoods and softwoods.

**3.5.3.2** ***Bending, tension and compression stresses***

For $r/t < 240$, the bending, tension and compression parallel to the grain grade stresses should be multiplied by the modification factor, $K_{33}$, where

$K_{33} = 0.76 + 0.001r/t$ and

$K_{33} \leq 1.0$

In curved beams where the ratio of the minimum mean radius of curvature, $r_{mean}$, to the depth, $h$, is less than or equal to 15, the bending stress induced by a moment, $M$, should be calculated as:

a) bending stress in the extreme fibre on the concave face,

$$\sigma_m = K_{34} \frac{6M}{bh^2}$$

where

$$K_{34} = 1 + \left(0.5 \frac{h}{r_{mean}}\right) \text{ for } \frac{r_{mean}}{h} \leq 10$$

and

$$K_{34} = 1.15 - \left(0.01 \frac{r_{mean}}{h}\right) \text{ for } 10 < \frac{r_{mean}}{h} \leq 15$$

b) bending stress in the extreme fibre on the convex face,

$$\sigma_m = \frac{6M}{bh^2}$$

**3.5.3.3** ***Radial stresses***

The radial stress, $\sigma_r$, induced by a bending moment, $M$, in a curved glued laminated beam of constant rectangular cross-section should be calculated using the following equation:

$$\sigma_r = \frac{3M}{2bhr_{mean}}$$

Where the moment tends to increase the radius of curvature of the beam, the radial stress will be tension perpendicular to the grain and the value of $\sigma_r$ should be not greater than the value derived in accordance with **3.2**.

Where the moment tends to reduce the radius of curvature, the radial stress will be compression perpendicular to the grain and the value of $\sigma_r$ should be not greater than 1.33 times the compression perpendicular to the grain stress for the strength class.



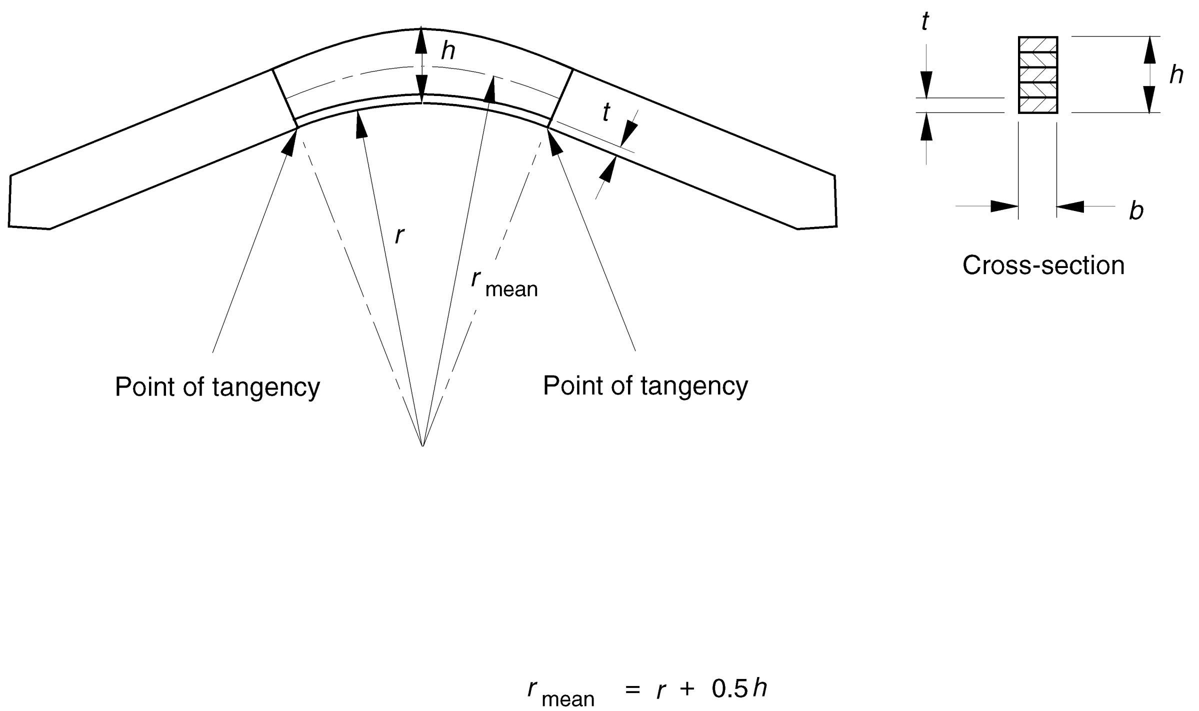



**Figure 4 — Curved glued laminated beam**

### 3.5.4 Pitched cambered softwood beams

#### 3.5.4.1 *Bending stress*

For pitched cambered beams of rectangular cross-section whose geometry and loading are symmetrical about the mid-span (see Figure 5), the bending stress at the apex is maximum at the soffit and should be calculated using the following equation:

$$\sigma_{m,apex} = \frac{(1.0 + 2.7 \tan a)}{bh_{apex}{}^2} 6M_{apex}$$

where

- $a$ is the slope of the upper surfaces of the beam in degrees (°);
- $M_{apex}$ is the bending moment at the apex;
- $h_{apex}$ is the depth of the section at the apex.

The bending stress at the point of tangency, $\sigma_{m,tang}$, should be calculated from:

$$\sigma_{m,tang} = \frac{6M_{tang}}{bh_{tang}{}^2}$$

where

- $M_{tang}$ is the bending moment at the point of tangency;
- $h_{tang}$ is the depth of the section at the point of tangency.

The bending stresses, $\sigma_{m,apex}$ and $\sigma_{m,tang}$, should be not greater than the appropriate permissible stress in bending parallel to the grain.

#### 3.5.4.2 *Radial stresses*

For pitched cambered beams of rectangular cross-section whose geometry and loadings are symmetrical about the mid-span (see Figure 5), the radial stress induced by bending is maximum near the mid-depth at the apex and should be calculated as the larger of a) or b):

a) $\sigma_r = K_{35} \dfrac{6M_{apex}}{rbh_{apex}{}^2}$

b) $\sigma_r = \dfrac{3M_{apex}}{2rbh_{apex}}$

where

$\sigma_r$ is the radial stress perpendicular to the grain;
$M_{apex}$ is the bending moment at the apex;
$r$ is the radius of curvature at the centre-line of the depth of the apex;
$b$ is the breadth of the section;
$h_{apex}$ is the total depth of the section at the apex;
$K_{35}$ is the stress modification factor given by

$$K_{35} = A + B\left(\frac{h_{apex}}{r}\right) + C\left(\frac{h_{apex}}{r}\right)^2$$

where

$A$, $B$ and $C$ are constants having the values given in Table 27.

NOTE The equation given in a) gives exact values of the radial stress at the apex only for the case of beams whose upper and lower surfaces are parallel, i.e. beams of constant depth except for the built-up portion at mid-span. It does, however, give a conservative approximation for all cases in which the beams are tapered in depth towards the supports.

**Table 27 — Values of constants for determining radial stresses in pitched cambered softwood beams**

| Slope of upper surface of beam [a] degrees | Value of constant | | |
|---|---|---|---|
| | *A* | *B* | *C* |
| 2.5 | 0.008 | 0.175 | 0.128 |
| 5 | 0.017 | 0.125 | 0.194 |
| 7.5 | 0.028 | 0.094 | 0.216 |
| 10 | 0.039 | 0.075 | 0.212 |
| 15 | 0.063 | 0.062 | 0.172 |
| 20 | 0.089 | 0.061 | 0.139 |
| 25 | 0.121 | 0.060 | 0.124 |
| 30 | 0.165 | 0.060 | 0.112 |

[a] Slope measured in degrees from the horizontal (see Figure 5).

The radial stresses at the tangent points should be calculated in accordance with **3.5.4.2**.

The radial stress, $\sigma_r$, should be not greater than the value derived in accordance with **3.2**.

## 3.6 Glued laminated compression members

The provisions of **2.11** apply also to glued laminated timber compression members.

The mean modulus of elasticity modified in accordance with **3.2** should be used to calculate the value of modification factor, $K_{12}$.

## 3.7 Glued laminated tension members

The provisions of **2.12** apply to glued laminated timber tension members.

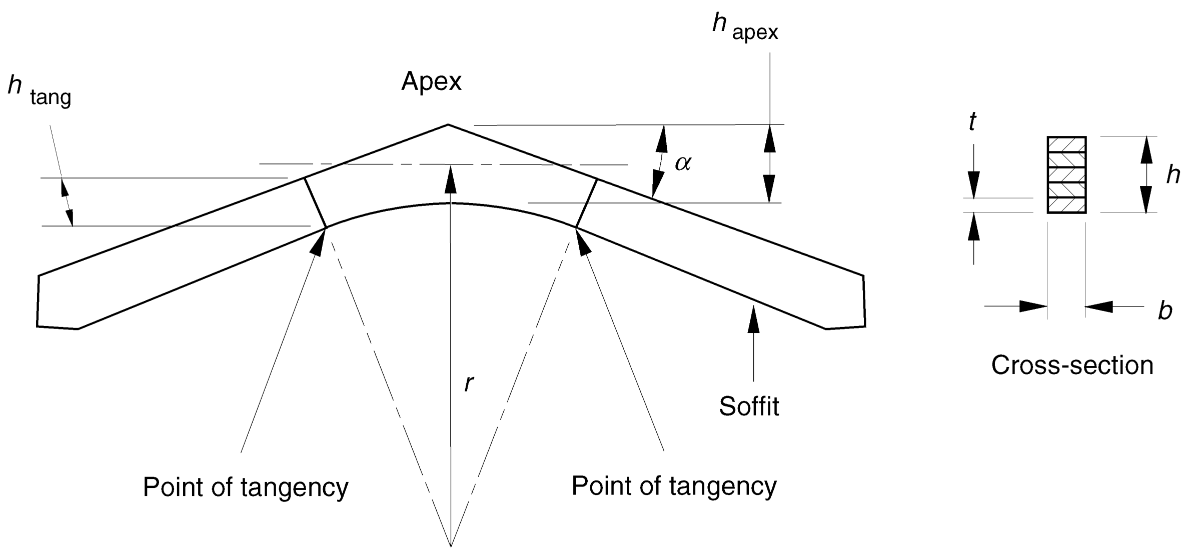



**Figure 5 — Pitched cambered beam**

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# Section 4. Plywood

## 4.1 General

This section gives recommendations for the use of sanded and unsanded plywoods manufactured in accordance with the standards listed in **1.5** and in the Bibliography, and subject to the quality control procedures of one of the following:

APA, The Engineered Wood Association

British Standards Institution (BSI)

Canadian Plywood Association (CANPLY)

Technical Research Centre of Finland (VTT)

The National Swedish Testing Institute (Statens Provningsanstalt)

TECO Corporation (TECO)

Special-purpose plywoods, and plywood with lay-ups other than those listed in the tables, may also be available but are not covered in this standard.

The strength of plywood depends mainly on total thickness, and on the species, grade, arrangement and thickness of the individual plies. When specifying plywood for structural work, reference should be made to the type, grade, panel nominal thickness, number of plies, and whether a sanded or unsanded finish is required.

Within a specification of panel nominal thickness and number of plies a range of constructions, combining plies of different thickness, may be available.

The tabulated section properties are based on the full cross-section ignoring the effect of orientation of veneers.

The tabulated grade stresses and moduli are based on strength and stiffness tests on plywoods of specified thickness and lay-up, allowing for the effect of orientation of veneers, and expressed in terms of the tabulated section properties.

The strength or stiffness capacity of a particular plywood is obtained by multiplying the appropriate stress or modulus value by the appropriate section property.

The species used to manufacture these plywoods are given in Annex D.

Alternatively, grade stresses and moduli may be derived by the equations given in **4.6** from characteristic values obtained from the appropriate European Standards for structural plywood, methods of test and derivation of characteristic values.

## 4.2 Durability

Although all the plywoods covered by BS 5268-2 are bonded with an exterior-type adhesive, this does not mean that they are necessarily suitable for use in damp or wet exposure conditions for long periods. Consideration should be given to the natural durability of the wood species from which the plywoods are made. Generally, plywoods used for permanent structures in damp or wet conditions, unless inherently durable, should be adequately treated against decay (see BS 5268-5 and DD ENV 1099). American plywood designated Exposure 1 is manufactured with exterior-type adhesive, but is not recommended for use in prolonged damp or wet conditions, as the inclusion of D-grade veneer in backs and inner plies of Exposure 1 boards could affect localized glue line performance. For applications subject to permanent outdoor exposure, a board of Exterior bond durability classification should be used.

## 4.3 Dimensions and section properties

The section properties of plywood are given in Table 28, Table 29, Table 30, Table 31, Table 32, Table 33, Table 34, Table 35 and Table 36. They are based on the minimum thicknesses permitted by the relevant product standards and apply to all service classes.

**Table 28 — Section properties of American construction and industrial plywood: unsanded and touch sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 8.0 | 3 | 7.1 | 7.1 | 8.4 | 29.8 | 4.6 |
| 9.5 | 3 | 8.7 | 8.7 | 12.6 | 54.9 | 5.4 |
| 11.5 | 3, 4 and 5 | 11.1 | 11.1 | 20.5 | 114.0 | 6.8 |
| 12.5 | 4 and 5 | 11.9 | 11.9 | 23.6 | 140.4 | 7.3 |
| 15.0 | 4 and 5 | 14.3 | 14.3 | 34.1 | 243.7 | 8.8 |
| 16.0 | 4 and 5 | 15.1 | 15.1 | 38.0 | 286.9 | 9.3 |
| 18.0 | 4 and 5 | 17.5 | 17.5 | 51.0 | 446.6 | 10.8 |
| 19.0 | 5 | 18.3 | 18.3 | 55.8 | 510.7 | 11.2 |
| 22.0 | 7 | 21.1 | 21.1 | 74.2 | 782.8 | 12.7 |

**Table 29 — Section properties of American construction and industrial plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 9.5 | 3 | 9.1 | 9.1 | 13.8 | 62.8 | 5.6 |
| 11.5 | 4 and 5 | 11.5 | 11.5 | 22.0 | 126.7 | 7.1 |
| 12.5 | 4 and 5 | 12.3 | 12.3 | 25.2 | 155.1 | 7.6 |
| 15.0 | 4 and 5 | 14.7 | 14.7 | 36.0 | 264.7 | 9.0 |
| 16.0 | 4 and 5 | 15.5 | 15.5 | 40.0 | 310.3 | 9.5 |
| 18.0 | 4 and 5 | 17.9 | 17.9 | 53.4 | 477.9 | 11.0 |
| 19.0 | 5 | 18.6 | 18.6 | 57.7 | 536.2 | 11.4 |
| 22.0 | 7 | 21.6 | 21.6 | 77.8 | 839.8 | 13.0 |

**Table 30 — Section properties of Canadian Douglas fir plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 14 | 5 and 6 | 13.5 | 13.5 | 30.4 | 205 | 6.4 |
| 17 | 5, 6 and 7 | 16.5 | 16.5 | 45.4 | 374 | 7.8 |
| 19 | 5, 6 and 7 | 18.5 | 18.5 | 57.0 | 528 | 8.7 |

**Table 31 — Section properties of Canadian Douglas fir and softwood plywood: unsanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 9.5 | 3 | 9 | 9 | 13.5 | 60.8 | 4.4 |
| 12.5 | 4 and 5 | 12 | 12 | 24.0 | 144 | 5.8 |
| 15.5 | 5 | 15 | 15 | 37.5 | 281 | 7.1 |
| 18.5 | 5, 6 and 7 | 18 | 18 | 54.0 | 486 | 8.5 |
| 20.5 | 6 and 7 | 20 | 20 | 66.7 | 667 | 9.4 |
| 22.5 | 7 and 8 | 22 | 22 | 80.7 | 887 | 10.4 |
| 25.5 | 7, 8 and 9 | 25 | 25 | 104 | 1 302 | 11.7 |
| 28.5 | 8, 9 and 11 | 28 | 28 | 131 | 1 829 | 13.1 |

**Table 32 — Section properties of Finnish birch plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 6.5 | 5 | 6.1 | 6.1 | 6.2 | 18.9 | 4.6 |
| 9 | 7 | 8.8 | 8.8 | 12.9 | 56.8 | 6.5 |
| 12 | 9 | 11.5 | 11.5 | 22.0 | 127 | 8.4 |
| 15 | 1 | 14.3 | 14.3 | 34.0 | 244 | 10.4 |
| 18 | 13 | 17.1 | 17.1 | 48.7 | 417 | 12.4 |
| 21 | 15 | 20.0 | 20.0 | 66.7 | 667 | 14.3 |
| 24 | 17 | 22.9 | 22.9 | 87.4 | 1 001 | 16.3 |
| 27 | 19 | 25.2 | 25.2 | 106 | 1 330 | 18.3 |
| 30 | 21 | 28.1 | 28.1 | 132 | 1 849 | 20.4 |

**Table 33 — Section properties of Finnish birch faced plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 6.5 | 5 | 6.1 | 6.1 | 6.2 | 18.9 | 4.4 |
| 9 | 7 | 8.8 | 8.8 | 12.9 | 56.8 | 6.2 |
| 12 | 7 and 9 | 11.5 | 11.5 | 22.0 | 127 | 8.1 |
| 15 | 9 and 11 | 13.9 | 13.9 | 32.2 | 224 | 9.9 |
| 18 | 11 and 13 | 17.1 | 17.1 | 48.7 | 417 | 11.6 |
| 21 | 11, 13 and 15 | 20.0 | 20.0 | 66.7 | 667 | 13.4 |
| 24 | 13, 15 and 17 | 22.9 | 22.9 | 87.4 | 1 001 | 15.2 |
| 27 | 17 and 19 | 25.2 | 25.2 | 106 | 1 330 | 17.0 |
| 30 | 17 and 21 | 28.1 | 28.1 | 132 | 1 849 | 17.1 |

**Table 34 — Section properties of Finnish conifer plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 6.5 | 5 | 6.1 | 6.1 | 6.2 | 18.9 | 3.9 |
| 9 | 3, 5 and 7 | 8.6 | 8.6 | 12.3 | 53.0 | 5.3 |
| 12 | 4, 5, 7 and 9 | 11.5 | 11.5 | 22.0 | 127 | 6.6 |
| 15 | 5, 7, 9 and 11 | 14.3 | 14.3 | 34.0 | 244 | 8.3 |
| 18 | 6, 7, 9, 11 and 13 | 17.1 | 17.1 | 48.7 | 417 | 9.8 |
| 21 | 7, 9, 11 and 15 | 20.0 | 20.0 | 66.7 | 667 | 11.4 |
| 24 | 8, 9, 11, 13 and 17 | 22.9 | 22.9 | 87.4 | 1 001 | 13.2 |
| 27 | 9, 11, 13 and 19 | 25.2 | 25.2 | 106 | 1 330 | 14.8 |
| 30 | 10, 13 and 21 | 28.1 | 28.1 | 132 | 1 848 | 15.8 |

**Table 35 — Section properties of Swedish softwood plywood: unsanded and touch sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 7 | 3 | 6.7 | 6.7 | 7.5 | 25.1 | 3.2 |
| 9 | 3 | 8.8 | 8.8 | 12.9 | 56.8 | 4.2 |
| 12 | 5 | 11.5 | 11.5 | 22.0 | 126.7 | 5.5 |
| 15 | 5 | 15.0 | 15.0 | 37.5 | 281.3 | 7.1 |
| 18 | 5 | 17.8 | 17.8 | 52.8 | 470.0 | 8.5 |
| 18 | 7 | 17.7 | 17.7 | 52.2 | 462.1 | 8.4 |
| 21 | 7 | 21.0 | 21.0 | 73.5 | 771.8 | 10.0 |
| 24 | 9 | 24.0 | 24.0 | 96.0 | 1 152.0 | 11.4 |

**Table 36 — Section properties of Swedish softwood plywood: sanded**

| Nominal thickness | Number of plies | Minimum thickness | Section properties for a 1 m width | | | Approximate mass per unit area |
|---|---|---|---|---|---|---|
| | | | Area | Section modulus | Second moment of area | |
| mm | | mm | $10^3$ mm$^2$ | $10^3$ mm$^3$ | $10^3$ mm$^4$ | kg/m$^2$ |
| 12.5 | 5 | 12.0 | 12.0 | 24.0 | 144 | 5.3 |
| 16 | 7 | 15.7 | 15.7 | 41.1 | 322 | 7.0 |
| 19 | 7 | 18.2 | 18.2 | 55.2 | 502 | 8.0 |
| 22 | 9 | 22.2 | 22.2 | 82.1 | 912 | 9.6 |
| 25 | 11 | 25.2 | 25.2 | 106 | 1 330 | 10.9 |

## 4.4 Grades

The grade stresses apply only to plywoods of the following grades, and bearing the following identification.

a) American construction and industrial plywoods.

1) C-D grade Exposure 1: grade C group 1 face veneer, grade D group 1 back veneer, grade D group 1 or 2 inner veneer: unsanded: the following wording is included in the board marking "APA or TECO: C-D Exposure 1, PS 1-95, BS 5268-2 **4.4**a)1)" (see Table 40). The stresses should not be used in conjunction with plywoods marked "butt-jointed centres".

2) C-C grade: grade C group 1 veneers throughout: unsanded: the following wording is included in the board marking "APA or TECO: C-C: Exterior, PS 1-95, BS 5268-2 **4.4**a)2)" (see Table 41).

3) A-C and B-C grade: grade A or grade B group 1 face veneer, grade C group 1 inner and back veneers: sanded: the following wording is included in the board marking "APA or TECO: A-C (or B-C) Exterior: PS 1-95, BS 5268-2 **4.4**a)3)" (see Table 42).

4) Underlayment and C-D plugged: grade C plugged group 1 face veneer, grade D group 1 back veneer, grade D groups 1 or 2 inner veneer (veneer below face may be C grade): touch sanded: marked "APA or TECO: Underlayment and/or with alphabetic grade letters: Exposure 1: PS 1-95, BS 5268-2 group 1 face and back, group 1 or 2 inner" (see Table 43).

5) Underlayment and C-C plugged: grade C plugged group 1 face veneer, grade C group 1 back veneer, grade C groups 1 or 2 inner veneer: touch sanded: marked "APA or TECO: Underlayment and/or with alphabetic grade letters: Exterior: PS 1-95, BS 5268-2 group 1 face and back, group 1 or 2 inner" (see Table 43).

Figure E.1 provides an example of the marks.

b) Canadian Douglas fir and softwood plywoods.

1) Sheathing grade: grade C veneers throughout: unsanded: marked "CANPLY: Exterior: DFP (or CSP): SHG" (see Table 44, Table 45 and Table 46).

2) Select grade: grade B face veneer and grade C inner and back veneers: unsanded: marked "CANPLY: Exterior: DFP (or CSP): Select" (see Table 44, Table 45 and Table 46).

3) Select tight face grade: grade B filled face veneer and grade C inner and back veneers: unsanded: marked "CANPLY: Exterior: DFP (or CSP): Select T.F." (see Table 44, Table 45 and Table 46).

Figure E.2 provides an example of the marks.

c) Finnish birch, birch-faced and conifer plywoods.

In addition to the requirements of the following Finnish and British Standards, the size of live knots in grade IV veneers should be not greater than 75 mm: SFS 2412, SFS 2413, SFS 4091, SFS 4092, BS EN 310, BS EN 314, BS EN 315, BS EN 322, BS EN 323 and BS EN 324.

1) Birch plywood: I/I, I/II, I/III, II/II, II/III, III/III, III/IV and IV/IV grades: constructed from birch veneers throughout with face veneer of the grade indicated by the first number, back veneer of the grade indicated by the second number and with inner veneers of minimum IV grade: sanded: marked "FINPLY ALL BIRCH" (see Table 32 and Table 49).

2) Birch-faced plywood: I/I, I/II, I/III, II/II, II/III, III/III, III/IV and IV/IV grades: constructed from birch face veneer of the grade indicated by the first number, birch back veneer of the grade indicated by the second number and inner veneers firstly of minimum grade IV birch and thereafter of minimum grade IV spruce and birch alternatively: sanded: marked "FINPLY COMBI" (see Table 33, Table 52 and Table 53).

3) Conifer plywood: I/I, I/II, I/III, II/II, II/III, III/III, III/IV and IV/IV grades: constructed from spruce and pine veneers throughout, the face veneer of the grade indicated by the first number, the back veneer of the grade indicated by the second number and inner veneers of minimum grade IV: sanded: marked "FINPLY CONIFER" (see Table 34, Table 50 and Table 51).

4) Birch-faced plywood: I/I, I/II, I/III, II/II, II/III, III/III, III/IV and IV/IV grades: constructed from birch face veneer of the grade indicated by the first number, birch back veneer of the grade indicated by the second number and inner veneers firstly of minimum grade IV spruce and thereafter of minimum grade IV birch and spruce alternatively: sanded: marked "FINPLY COMBI MIRROR" (see Table 33 and Table 54).

5) Birch-faced plywood: I/I, I/II, I/III, II/II, II/III, III/III, III/IV and IV/IV grades: constructed from birch face veneer of the grade indicated by the first number, birch back veneer of the grade indicated by the second number and inner veneers of minimum grade IV spruce: sanded: marked "FINPLY TWIN" (see Table 33 and Table 55).

Figure E.3 provides an example of the marks.

d) Swedish softwood plywood.

P 30 grade: constructed from spruce or pine veneers of P 30 grade: unsanded and sanded: marked "P 30 EXTERIOR GLUE" with Trident (see Table 56).

Figure E.4 provides an example of the marks.

## 4.5 Grade stresses and moduli

The grade stresses and moduli for plywoods are given in Table 40, Table 41, Table 42, Table 43, Table 44, Table 45, Table 46, Table 49, Table 50, Table 51, Table 52, Table 53, Table 54, Table 55 and Table 56. These apply to long-term loading in service classes 1 and 2, and should be used in conjunction with the corresponding section properties given in Table 28, Table 29, Table 30, Table 31, Table 32, Table 33, Table 34, Table 35 and Table 36. For other durations of load and/or the service class 3 condition, the stresses and moduli should be multiplied by the modification factor, $K_{36}$, given in Table 39.

## 4.6 Design data derived from characteristic values

Characteristic values should be derived in accordance with:

a) BS EN 789 and BS EN 1058 or from tests in accordance with BS EN 12369-2 (in preparation) for plywoods conforming to European Standards listed therein; or

b) BS EN 789 and BS EN 1058 for plywood conforming to those sections of prEN 13986 that relate to plywood for structural components; or

c) BS EN 789 and BS EN 1058 for plywood conforming to those sections of BS EN 636-1, -2 or -3 that relate to structural applications.

Specifiers should also take into account the appropriate bonding quality and biological durability for the particular end use application to which the plywood is being put (see the relevant sections of BS EN 636-1, -2 or -3 as appropriate).

Characteristic strength values are defined as the population 5-percentile value obtained from tests with a duration of 300 s using test pieces at an equilibrium moisture content resulting from a temperature of 20 °C and a relative humidity of 65 %. Characteristic moduli values are defined as either the 5-percentile value or the mean value, under the same test conditions as defined above.

Characteristic strength values should be converted into grade strength values for the permissible stress basis of design by:

$$X_d = k_{mod} X_k / (1.35 \gamma_M)$$

where

$X_d$ is the grade strength value;

$X_k$ is the characteristic strength value;

$k_{mod}$ is the modification factor for duration of loading and service class given in Table 37;

$\gamma_M$ is the material partial safety factor (e.g. 1.2 for plywood).

When a modification factor, $k_{mod}$, greater than unity is used in accordance with this clause, the design should be checked to ensure that the permissible stresses are not exceeded for any other condition of loading that might be relevant.

Characteristic moduli values should be converted into grade moduli values for the permissible stress basis of design by:

$E_d = E_k/(1 + k_{def})$

where

$E_d$ is the grade modulus value;

$E_k$ is the characteristic modulus value (mean or minimum value as relevant) obtained from tests;

$k_{def}$ is the modification factor for creep deformation and service class given in Table 38;

The deflections or deformations of a structural member subject to a combination of loads of different duration should be determined by considering the load in each category as acting separately, and calculating the deflections or deformations induced by each, using the appropriate moduli values.

**Table 37 — Modification factor, $k_{mod}$, for duration of loading and service class for plywood**

| Duration of loading | Service class | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Long-term | 0.60 | 0.60 | 0.50 |
| Medium-term | 0.86 | 0.86 | 0.68 |
| Test duration | 1.02 | 1.02 | 0.82 |
| Short-term | 1.06 | 1.06 | 0.86 |
| Very short-term | 1.08 | 1.08 | 0.88 |

**Table 38 — Modification factor, $k_{def}$, for elastic or shear modulus for plywood**

| Duration of loading | Service class | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Long-term | 0.80 | 1.00 | 2.50 |
| Medium-term | 0.11 | 0.14 | 0.62 |
| Test duration | 0.00 | 0.00 | 0.00 |
| Short-term | 0.00 | 0.00 | 0.00 |
| Very short-term | 0.00 | 0.00 | 0.00 |

## 4.7 Flexural members

The permissible stresses for plywood in flexural members are governed by the particular conditions of service and loading described in **2.8** and **2.9** and should be taken as the product of the grade stresses given in Table 40, Table 41, Table 42, Table 43, Table 44, Table 45, Table 46, Table 49, Table 50, Table 51, Table 52, Table 53, Table 54, Table 55 and Table 56 and the appropriate modification factors from **4.5**.

The full cross-section of the plywood should be assumed to act with stresses in tension, compression, bending and panel shear, whether the direction of the stress is parallel or perpendicular to the grain of the face ply.

The bending stresses and moduli given in Table 40, Table 41, Table 42, Table 43, Table 44, Table 45, Table 46, Table 49, Table 50, Table 51, Table 52, Table 53, Table 54, Table 55 and Table 56 apply when the bending is about either of the axes in the plane of the board. When bending is about the axis perpendicular to the plane of the board (i.e. with the edge loaded, as in a built-in I-beam) the tensile and compressive stresses induced by the bending moment should be considered individually, and the tension and compression stresses and moduli for the appropriate face grain orientation should be used.

In box beams or I-beams, or stressed skin panels having plywood covers, only the area of contact between the plywood and framing members should be considered in calculating rolling shear. For rolling shear at the junction of the web and flange of a plywood webbed beam, and at the junction of the outermost longitudinal member and plywood cover of a stressed skin panel, the grade stresses given in Table 40, Table 41, Table 42, Table 43, Table 44, Table 45, Table 46, Table 49, Table 50, Table 51, Table 52, Table 53, Table 54, Table 55 and Table 56 should be multiplied by the stress concentration modification factor, $K_{37}$, which has the value 0.5.

The deflection of box beams and I-beams due to bending should be calculated using the full cross-section properties of the plywood and timber. The shear deflection of a beam may be significant, and should be taken into account.

The values of modulus of elasticity in bending given in Table 40, Table 41, Table 42, Table 43, Table 44, Table 45, Table 46, Table 49, Table 50, Table 51, Table 52, Table 53, Table 54, Table 55 and Table 56 are true moduli, i.e. shear is not included.

When considering lateral stability, reference should also be made to **2.10.8** and **2.10.10**.

## 4.8 Plywoods for roof and floor decking

The design of plywood for decking on roofs and floors should be determined:

a) by calculation using grade stresses and moduli; or

b) where used for buildings, by testing on samples of typical roof or floor assemblies with the product supported on joists, under impact and concentrated static loads (of the appropriate contact area) in accordance with BS EN 1195 (see **8.9**) to satisfy the performance specification and requirements in BS EN 12871 and **8.9**. The application of plywood for these purposes should comply with BS EN 12872.

The requirement in BS EN 12871 to verify the design by calculation for uniformly distributed loading need not be made where all of the following conditions apply.

1) The specified imposed loading is in accordance with BS 6399 but excluding loading for vehicle traffic areas.

2) The ratio of uniformly distributed load (in kN/m$^2$) to the related concentrated load (in kN) does not exceed 1.5.

3) The maximum span of the panel product in the roof or floor decking is not more than 1.00 m.

This method of design does not apply to garage and vehicle traffic areas and roofs for special services such as helicopter landings.

**Table 39 — Modification factor, $K_{36}$, by which the grade stresses and moduli for long-term duration and service classes 1 and 2 for plywood should be multiplied to obtain values for other durations and/or service class 3**

| Duration of loading | Value of $K_{36}$ | | | |
|---|---|---|---|---|
| | Service classes 1 and 2 | | Service class 3 | |
| | Stress | Modulus | Stress | Modulus |
| Long-term | 1.00 | 1.00 | 0.83 | 0.57 |
| Medium-term | 1.33 | 1.54 | 1.08 | 1.06 |
| Short- and very short-term | 1.50 | 2.00 | 1.17 | 1.43 |

NOTE 1 For uniformly distributed imposed floor loads $K_{36}$ = 1 except for type 2 and type 3 buildings given in Table 5 of BS 6399-1:1984 where, for corridors, hallways, landings and stairways only, $K_{36}$ may be assumed to be short-term.

NOTE 2 For wind, short-term category applies to class C (15 s gust) as defined in CP 3:Chapter V-2 or where the largest diagonal dimension of the loaded area, $a$, as defined in BS 6399-2, exceeds 50 m.

NOTE 3 For wind, very short-term category applies to classes A and B (3 s or 5 s gust) as defined in CP 3:Chapter V-2 or where the largest diagonal dimension of the loaded area, $a$, as defined in BS 6399-2, does not exceed 50 m.

**Table 40 — Grade stresses and moduli for service classes 1 and 2 for American plywood: C-D grade Exposure 1 [a]: unsanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 (3) | 9.5 (3) | 11.5 (3) | 11.5 (4) | 11.5 (5) | 12.5 (4) | 12.5 (5) | 15 (4) | 15 (5) | 16 (4) | 16 (5) | 18 (4) | 18 (5) | 19 (5) | 21 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | | | | | | | |
| Extreme fibre in bending [b]: | | | | | | | | | | | | | | | |
| — face grain parallel to span | 7.19 | 6.80 | 7.49 | 6.06 | 10.19 | 7.09 | 11.57 | 6.70 | 8.82 | 6.40 | 9.70 | 7.24 | 8.82 | 7.83 | 7.29 |
| — face grain perpendicular to span | 2.51 | 2.66 | 2.71 | 4.73 | 5.27 | 5.17 | 6.01 | 5.02 | 3.15 | 4.97 | 5.81 | 3.15 | 4.33 | 5.71 | 4.97 |
| Tension[b]: | | | | | | | | | | | | | | | |
| — parallel to face grain | 4.63 | 3.64 | 3.64 | 3.64 | 6.40 | 3.69 | 6.70 | 3.69 | 4.24 | 3.60 | 5.17 | 4.53 | 4.97 | 5.57 | 5.17 |
| — perpendicular to face grain | 0.98 | 0.98 | 1.72 | 3.20 | 3.30 | 3.35 | 3.55 | 3.10 | 3.35 | 3.35 | 3.55 | 3.60 | 2.95 | 3.74 | 3.40 |
| Compression [b]: | | | | | | | | | | | | | | | |
| — parallel to face grain | 7.19 | 5.71 | 6.99 | 5.42 | 6.65 | 5.66 | 6.85 | 5.61 | 4.28 | 5.27 | 5.27 | 4.73 | 5.57 | 5.76 | 5.22 |
| — perpendicular to face grain | 3.20 | 3.25 | 4.14 | 4.83 | 3.64 | 5.07 | 3.99 | 4.24 | 3.69 | 3.94 | 3.94 | 3.99 | 4.09 | 4.19 | 3.79 |
| Bearing: | | | | | | | | | | | | | | | |
| — on face | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 |
| Rolling shear: | | | | | | | | | | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glueline | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | | | | | | | | |
| — bending: | | | | | | | | | | | | | | | |
| — face grain parallel to span | 0.35 | 0.34 | 0.35 | 0.37 | 0.40 | 0.37 | 0.39 | 0.36 | 0.40 | 0.37 | 0.38 | 0.37 | 0.39 | 0.39 | 0.36 |
| — face grain perpendicular to span | 0.66 | 0.66 | 0.66 | 0.74 | 0.22 | 0.74 | 0.22 | 0.67 | 0.22 | 0.74 | 0.22 | 0.73 | 0.22 | 0.22 | 0.27 |

[a] For prolonged use in damp or wet conditions select C-C grade in lieu of C-D grade.
[b] For panels less than 600 mm wide, the bending, tension and compression stresses should be reduced in proportion to their width, commencing with no reduction at 600 mm to 50 % at 200 mm and less.

**Table 40 — Grade stresses and moduli for service classes 1 and 2 for American plywood: C-D grade Exposure 1 [a]: unsanded** *(continued)*

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 (3) | 9.5 (3) | 11.5 (3) | 11.5 (4) | 11.5 (5) | 12.5 (4) | 12.5 (5) | 15 (4) | 15 (5) | 16 (4) | 16 (5) | 18 (4) | 18 (5) | 19 (5) | 21 (7) |
| | Grade stress or modulus N/mm² | | | | | | | | | | | | | | |
| Panel shear: | | | | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| Modulus of elasticity in bending: | | | | | | | | | | | | | | | |
| — face grain parallel to span | 5 400 | 5 300 | 5 200 | 4 950 | 5 500 | 4 650 | 5 150 | 4 600 | 4 450 | 4 250 | 4 250 | 4 150 | 4 150 | 4 000 | 3 900 |
| — face grain perpendicular to span | 375 | 325 | 350 | 900 | 1 350 | 850 | 1 250 | 1 050 | 750 | 850 | 1 200 | 750 | 1 250 | 1 200 | 1 250 |
| Modulus of elasticity in tension and compression: | | | | | | | | | | | | | | | |
| — parallel to face grain | 3 650 | 2 850 | 2 750 | 2 900 | 3 500 | 2 850 | 3 400 | 2 650 | 2 250 | 2 800 | 2 650 | 2 450 | 2 900 | 2 850 | 2 600 |
| — perpendicular to face grain | 1 800 | 1 850 | 1 800 | 2 900 | 2 350 | 2 850 | 2 300 | 2 350 | 2 250 | 2 200 | 2 200 | 2 150 | 2 150 | 2 150 | 1 950 |
| Shear modulus (for panel shear): | | | | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |

[a] For prolonged use in damp or wet conditions select C-C grade in lieu of C-D grade.

[b] For panels less than 600 mm wide, the bending, tension and compression stresses should be reduced in proportion to their width, commencing with no reduction at 600 mm to 50 % at 200 mm and less.

**Table 41 — Grade stresses and moduli for service classes 1 and 2 for American plywood: C-C. Exterior. Group 1: unsanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 (3) | 9.5 (3) | 11.5 (4) | 11.5 (5) | 12.5 (4) | 12.5 (5) | 15 (4) | 15 (5) | 16 (4) | 18 (5) | 19 (5) | 22 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | | | | |
| Extreme fibre in bending [a]: | | | | | | | | | | | | |
| — face grain parallel to span | 8.62 | 8.18 | 7.29 | 12.21 | 7.98 | 12.07 | 7.78 | 10.59 | 7.63 | 8.67 | 9.36 | 8.42 |
| — face grain perpendicular to span | 3.00 | 3.15 | 5.61 | 6.35 | 6.21 | 7.19 | 5.91 | 6.35 | 5.96 | 6.35 | 6.85 | 8.08 |
| Tension[a]: | | | | | | | | | | | | |
| — parallel to face grain | 5.12 | 4.04 | 3.79 | 7.19 | 3.99 | 7.39 | 3.89 | 5.57 | 3.89 | 6.06 | 6.16 | 5.27 |
| — perpendicular to face grain | 3.20 | 3.25 | 3.55 | 3.55 | 3.64 | 3.89 | 3.40 | 3.60 | 3.55 | 3.94 | 4.14 | 3.40 |
| Compression[a]: | | | | | | | | | | | | |
| — parallel to face grain | 7.78 | 6.06 | 5.76 | 7.04 | 6.01 | 7.29 | 6.01 | 5.57 | 5.57 | 6.01 | 6.11 | 5.17 |
| — perpendicular to face grain | 3.45 | 3.50 | 5.12 | 3.94 | 5.32 | 4.24 | 4.43 | 3.94 | 4.14 | 4.24 | 4.48 | 3.69 |
| Bearing: | | | | | | | | | | | | |
| — on face | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 |
| Rolling shear: | | | | | | | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glueline | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | | | | | |
| — bending: | | | | | | | | | | | | |
| — face grain parallel to span | 0.48 | 0.52 | 0.51 | 0.54 | 0.51 | 0.55 | 0.49 | 0.54 | 0.57 | 0.53 | 0.57 | 0.48 |
| — face grain perpendicular to span | 0.76 | 0.76 | 0.89 | 0.30 | 0.89 | 0.30 | 0.79 | 0.30 | 0.89 | 0.29 | 0.29 | 0.37 |
| Panel shear: | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| Modulus of elasticity in bending: | | | | | | | | | | | | |
| — face grain parallel to span | 5 400 | 5 300 | 4 950 | 5 500 | 4 650 | 5 150 | 4 600 | 4 450 | 4 250 | 4 150 | 4 000 | 3 600 |
| — face grain perpendicular to span | 375 | 325 | 900 | 1 350 | 850 | 1 250 | 1 050 | 1 250 | 850 | 1 250 | 1 200 | 1 700 |
| Modulus of elasticity in tension and compression: | | | | | | | | | | | | |
| — parallel to face grain | 3 650 | 2 850 | 2 900 | 3 500 | 2 850 | 3 400 | 2 650 | 2 650 | 2 800 | 2 900 | 2 850 | 2 450 |
| — perpendicular to face grain | 1 800 | 1 850 | 2 900 | 2 350 | 2 850 | 2 300 | 2 350 | 2 250 | 2 200 | 2 150 | 2 150 | 1 950 |
| Shear modulus (for panel shear): | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |

[a] For panels less than 600 mm wide, the bending, tension and compression stresses should be reduced in proportion to their width, commencing with no reduction at 600 mm to 50 % at 200 mm and less.

**Table 42 — Grade stresses and moduli for service classes 1 and 2 for American plywood: A-C and B-C. Exterior. Group 1: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.5 (3) | 11.5 (4) | 11.5 (5) | 12.5 (4) | 12.5 (5) | 15 (4) | 15 (5) | 16 (4) | 16 (5) | 18 (4) | 18 (5) | 19 (5) | 22 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | | | | | |
| Extreme fibre in bending [a]: | | | | | | | | | | | | | |
| — face grain parallel to span | 8.38 | 5.99 | 9.03 | 6.44 | 8.72 | 5.84 | 8.12 | 5.57 | 7.62 | 6.26 | 7.90 | 7.40 | 8.24 |
| — face grain perpendicular to span | 4.98 | 6.38 | 5.80 | 6.68 | 6.13 | 5.83 | 6.00 | 5.49 | 5.58 | 4.93 | 4.91 | 6.07 | 4.54 |
| Tension[a]: | | | | | | | | | | | | | |
| — parallel to face grain | 2.76 | 3.15 | 4.35 | 2.96 | 4.24 | 2.70 | 4.10 | 2.57 | 4.01 | 2.83 | 5.01 | 5.45 | 5.77 |
| — perpendicular to face grain | 1.05 | 5.40 | 4.43 | 5.65 | 4.56 | 4.29 | 3.84 | 4.50 | 3.94 | 3.67 | 3.38 | 3.18 | 2.83 |
| Compression[a]: | | | | | | | | | | | | | |
| — parallel to face grain | 7.45 | 7.79 | 11.52 | 7.29 | 8.73 | 8.44 | 10.06 | 8.01 | 9.84 | 7.51 | 8.45 | 9.19 | 9.74 |
| — perpendicular to face grain | 8.83 | 12.10 | 9.80 | 12.64 | 10.09 | 11.25 | 8.92 | 11.75 | 9.16 | 10.73 | 8.33 | 7.83 | 6.95 |
| Bearing: | | | | | | | | | | | | | |
| — on face | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 |
| Rolling shear: | | | | | | | | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glueline | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | | | | | | |
| — bending: | | | | | | | | | | | | | |
| — face grain parallel to span | 0.54 | 0.51 | 0.54 | 0.57 | 0.58 | 0.52 | 0.59 | 0.52 | 0.59 | 0.52 | 0.54 | 0.61 | 0.47 |
| — face grain perpendicular to span | 1.03 | 0.90 | 0.29 | 1.17 | 0.35 | 0.27 | 0.39 | 0.27 | 0.39 | 0.27 | 0.29 | 0.39 | 0.45 |
| Panel shear: | | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 | 1.53 |
| Modulus of elasticity in bending: | | | | | | | | | | | | | |
| — face grain parallel to span | 5 097 | 4 689 | 4 469 | 4 257 | 4 293 | 4 891 | 4 493 | 4 699 | 3 799 | 5 012 | 4 180 | 3 930 | 4 360 |
| — face grain perpendicular to span | 858 | 1 421 | 2 178 | 1 518 | 2 348 | 1 318 | 2 112 | 1 215 | 1 977 | 1 209 | 1 900 | 1 834 | 1 577 |
| Modulus of elasticity in tension and compression: | | | | | | | | | | | | | |
| — parallel to face grain | 3 303 | 2 661 | 4 304 | 2 476 | 4 191 | 2 996 | 3 357 | 2 849 | 3 279 | 3 164 | 3 802 | 4 149 | 4 395 |
| — perpendicular to face grain | 3 402 | 4 217 | 3 373 | 4 407 | 3 472 | 4 006 | 2 946 | 4 182 | 3 016 | 4 045 | 3 467 | 3 268 | 2 901 |
| Shear modulus (for panel shear): | | | | | | | | | | | | | |
| — parallel and perpendicular to face grain | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |

[a] For panels less than 600 mm wide, the bending, tension and compression stresses should be reduced in peoportion to theie width, commencing with no reduction at 600 mm to 50 % at 200 mm and less.

**Table 43 — Grade stresses and moduli for service classes 1 and 2 for American plywood. Underlayment and C-D plugged Exposure 1 Underlayment and C-C plugged Exterior: touch sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | |
|---|---|---|---|---|---|---|
| | 12.5 (4) | 12.5 (5) | 15 (5) | 16 (5) | 18 (5) | 19 (5) |
| | Grade stress or modulus N/mm$^2$ | | | | | |
| Extreme fibre in bending [a]: | | | | | | |
| — face grain parallel to span | 5.27 | 10.24 | 8.82 | 8.37 | 8.22 | 7.88 |
| — face grain perpendicular to span | 5.81 | 6.80 | 6.40 | 6.40 | 6.01 | 6.01 |
| Tension [a]: | | | | | | |
| — parallel to face grain | 3.35 | 6.35 | 5.02 | 4.88 | 5.42 | 5.32 |
| — perpendicular to face grain | 3.64 | 3.79 | 3.69 | 3.74 | 3.89 | 3.84 |
| Compression [a]: | | | | | | |
| — parallel to face grain | 5.22 | 6.45 | 5.07 | 4.97 | 5.61 | 5.42 |
| — perpendicular to face grain | 5.32 | 4.24 | 4.14 | 4.14 | 4.38 | 4.33 |
| Bearing: | | | | | | |
| — on face | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 | 2.67 |
| Rolling shear in plane of plies: | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glueline | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | |
| — bending: | | | | | | |
| — face grain parallel to span | 0.37 | 0.39 | 0.40 | 0.38 | 0.39 | 0.39 |
| — face grain perpendicular to span | 0.74 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Panel shear: | | | | | | |
| — parallel and perpendicular to face grain | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| Modulus of elasticity in bending: | | | | | | |
| — face grain parallel to span | 5 400 | 4 750 | 4 000 | 3 900 | 3 850 | 3 650 |
| — face grain perpendicular to span | 1 000 | 1 500 | 1 400 | 1 400 | 1 300 | 1 300 |
| Modulus of elasticity in tension and compression: | | | | | | |
| — parallel to face grain | 2 650 | 3 300 | 2 550 | 2 500 | 2 800 | 2 700 |
| — perpendicular to face grain | 3 040 | 2 440 | 2 367 | 2 344 | 2 445 | 2 448 |
| Shear modulus (for panel shear): | | | | | | |
| — parallel and perpendicular to face grain | 250 | 250 | 250 | 250 | 250 | 250 |

[a] For panels less than 600 mm wide, the bending, tension and compression stresses should be reduced in proportion with their width, commencing with no reduction at 600 mm to 50 % at 200 mm and less.

**Table 44 — Grade stresses and moduli for service classes 1 and 2 for Canadian softwood plywood: select tight face, select and sheathing grades: unsanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 9.5 (3) | 12.5 (4) | 12.5 (5) | 15.5 (5) | 18.5 (5) | 18.5 (6) | 18.5 (7) | 20.5 (6) | 20.5 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | |
| — face grain parallel to span | 11.1 | 11.0 | 9.95 | 8.82 | 10.4 | 9.36 | 8.77 | 7.53 | 8.13 |
| — face grain perpendicular to span | 2.66 | 3.44 | 5.12 | 4.73 | 5.47 | 5.27 | 5.32 | 5.32 | 5.37 |
| Tension: | | | | | | | | | |
| — parallel to face grain | 4.78 | 4.53 | 5.47 | 4.38 | 5.61 | 5.52 | 4.92 | 4.78 | 4.43 |
| — perpendicular to face grain | 2.12 | 3.15 | 3.64 | 2.91 | 3.79 | 2.46 | 3.69 | 2.22 | 3.30 |
| Compression: | | | | | | | | | |
| — parallel to face grain | 6.25 | 5.96 | 7.14 | 5.76 | 7.39 | 7.24 | 6.45 | 6.30 | 5.81 |
| — perpendicular to face grain | 3.94 | 5.76 | 4.78 | 3.84 | 4.97 | 3.20 | 4.83 | 2.91 | 4.38 |
| Bearing: | | | | | | | | | |
| — on face | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 |
| Rolling shear in plane of plies: | | | | | | | | | |
| — in face veneer | | | | | | | | | |
| — in back veneer | 0.39 | 0.39 | 0.51 | 0.51 | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 |
| — at first glueline | | | | | | | | | |
| Transverse shear: | | | | | | | | | |
| — bending: | | | | | | | | | |
| — face grain parallel to span | 0.44 | 0.45 | 0.62 | 0.65 | 0.63 | 0.66 | 0.56 | 0.54 | 0.56 |
| — face grain perpendicular to span | 0.55 | 0.64 | 0.32 | 0.33 | 0.32 | 0.31 | 0.41 | 0.33 | 0.44 |
| Panel shear: | | | | | | | | | |
| — parallel and perpendicular to face grain | 1.72 | 1.72 | 1.72 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 |
| Modulus of elasticity in bending: | | | | | | | | | |
| — face grain parallel to span | 4 165 | 4 160 | 3 755 | 3 370 | 4 020 | 3 605 | 3 370 | 2 190 | 3 130 |
| — face grain perpendicular to span | 245 | 615 | 1 135 | 1 055 | 1 255 | 1 320 | 1 335 | 1 410 | 1 420 |
| Modulus of elasticity in tension and compression: | | | | | | | | | |
| — parallel to face grain | 2 600 | 2 470 | 2 965 | 2 390 | 3 060 | 3 005 | 2 670 | 2 615 | 2 410 |
| — perpendicular to face grain | 1 625 | 2 390 | 1 980 | 1 595 | 2 060 | 1 335 | 2 005 | 1 205 | 1 810 |
| Shear modulus (for panel shear): | | | | | | | | | |
| — parallel and perpendicular to face grain | 210 | 215 | 215 | 215 | 220 | 220 | 220 | 220 | 220 |

**Table 44 — Grade stresses and moduli for service classes 1 and 2 for Canadian softwood plywood: select tight face, select and sheathing grades: unsanded** *(continued)*

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 22.5 (7) | 22.5 (8) | 25.5 (7) | 25.5 (8) | 25.5 (9) | 28.5 (8) | 28.5 (9) | 28.5 (11) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 8.72 | 9.16 | 8.37 | 8.47 | 8.77 | 8.08 | 8.08 | 8.86 |
| — face grain perpendicular to span | 5.07 | 5.07 | 6.21 | 5.32 | 5.32 | 6.25 | 5.12 | 5.76 |
| Tension: | | | | | | | | |
| — parallel to face grain | 4.53 | 4.53 | 4.78 | 3.99 | 4.88 | 3.89 | 4.38 | 5.17 |
| — perpendicular to face grain | 3.20 | 4.04 | 3.99 | 3.99 | 3.55 | 4.58 | 3.20 | 3.99 |
| Compression: | | | | | | | | |
| — parallel to face grain | 5.96 | 5.96 | 6.25 | 5.27 | 6.40 | 5.12 | 5.76 | 6.80 |
| — perpendicular to face grain | 4.19 | 5.32 | 5.22 | 5.22 | 4.68 | 6.00 | 4.19 | 5.22 |
| Bearing: | | | | | | | | |
| — on face | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 |
| Rolling shear in plane of plies: | | | | | | | | |
| — in face veneer<br>— in back veneer<br>— at first glueline | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 | 0.51 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.57 | 0.44 | 0.55 | 0.44 | 0.58 | 0.44 | 0.59 | 0.55 |
| — face grain perpendicular to span | 0.46 | 0.48 | 0.48 | 0.51 | 0.42 | 0.53 | 0.44 | 0.44 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 3 360 | 3 540 | 3 250 | 3 275 | 3 390 | 3 140 | 3 145 | 3 450 |
| — face grain perpendicular to span | 1 400 | 1 380 | 1 805 | 1 535 | 1 545 | 1 880 | 1 550 | 1 745 |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 2 470 | 2 470 | 2 605 | 2 180 | 2 665 | 2 130 | 2 385 | 2 820 |
| — perpendicular to face grain | 1 740 | 2 195 | 2 160 | 2 160 | 1 940 | 2 495 | 1 735 | 2 170 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 220 | 220 | 220 | 220 | 220 | 220 | 220 | 220 |

**Table 45 — Grade stresses and moduli for service classes 1 and 2 for Canadian Douglas fir plywood: select tight face, select and sheathing grades: unsanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 7.5 (3) | 9.5 (3) | 12.5 (4) | 12.5 (5) | 15.5 (5) | 18.5 (5) | 18.5 (6) | 18.5 (7) | 20.5 (6) | 20.5 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | | |
| — face grain parallel to span | 13.0 | 12.2 | 10.9 | 14.5 | 12.9 | 15.3 | 11.7 | 12.4 | 10.9 | 11.5 |
| — face grain perpendicular to span | 2.71 | 2.66 | 3.45 | 5.12 | 4.73 | 5.47 | 5.27 | 5.32 | 5.32 | 5.37 |
| Tension: | | | | | | | | | | |
| — parallel to face grain | 8.27 | 6.55 | 4.97 | 6.65 | 5.37 | 6.89 | 5.61 | 5.61 | 5.42 | 5.07 |
| — perpendicular to face grain | 2.17 | 2.12 | 3.15 | 3.64 | 2.91 | 3.79 | 2.46 | 3.69 | 2.22 | 3.30 |
| Compression: | | | | | | | | | | |
| —parallel to face grain | 12.5 | 9.90 | 7.49 | 10.0 | 8.13 | 10.4 | 8.52 | 8.52 | 8.18 | 7.68 |
| — perpendicular to face grain | 3.99 | 3.94 | 5.76 | 4.78 | 3.84 | 4.97 | 3.20 | 4.83 | 2.91 | 4.38 |
| Bearing: | | | | | | | | | | |
| — on face | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 |
| Rolling shear in plane of plies:<br>— in face veneer<br>— in back veneer<br>— at first glueline | 0.51 | 0.39 | 0.39 | 0.51 | 0.51 | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 |
| Transverse shear: | | | | | | | | | | |
| — bending: | | | | | | | | | | |
| — face grain parallel to span | 0.53 | 0.44 | 0.47 | 0.62 | 0.65 | 0.63 | 0.53 | 0.56 | 0.54 | 0.56 |
| — face grain perpendicular to span | 0.68 | 0.68 | 0.73 | 0.32 | 0.33 | 0.32 | 0.31 | 0.41 | 0.33 | 0.44 |
| Panel shear: | | | | | | | | | | |
| — parallel and perpendicular to face grain | 1.72 | 1.72 | 1.72 | 1.72 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 |
| Modulus of elasticity in bending: | | | | | | | | | | |
| — face grain parallel to span | 6 475 | 6 145 | 5 490 | 5 525 | 4 965 | 5 920 | 4 550 | 4 810 | 4 245 | 4 465 |
| — face grain perpendicular to span | 255 | 245 | 615 | 1 135 | 1 055 | 1 255 | 1 320 | 1 335 | 1 410 | 1 420 |
| Modulus of elasticity in tension and compression: | | | | | | | | | | |
| — parallel to face grain | 4 865 | 3 840 | 2 920 | 3 905 | 3 150 | 4 040 | 3 310 | 3 310 | 3 185 | 2 985 |
| — perpendicular to face grain | 1 650 | 1 625 | 2 390 | 1 980 | 1 595 | 2 060 | 1 335 | 2 005 | 1 205 | 1 810 |
| Shear modulus (for panel shear): | | | | | | | | | | |
| — parallel and perpendicular to face grain | 285 | 275 | 260 | 260 | 255 | 265 | 250 | 250 | 245 | 245 |

**Table 45 — Grade stresses and moduli for service classes 1 and 2 for Canadian Douglas fir plywood: select tight face, select and sheathing grades: unsanded** *(continued)*

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 22.5 (7) | 22.5 (8) | 25.5 (7) | 25.5 (8) | 25.5 (9) | 28.5 (8) | 28.5 (9) | 28.5 (11) |
| | Grade stress or modulus $N/mm^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 12.4 | 12.9 | 11.8 | 11.9 | 12.2 | 11.2 | 11.2 | 12 |
| — face grain perpendicular to span | 5.07 | 5.07 | 6.21 | 5.32 | 5.32 | 6.25 | 5.12 | 5.76 |
| Tension: | | | | | | | | |
| — parallel to face grain | 5.32 | 5.32 | 5.42 | 4.68 | 5.52 | 4.53 | 4.92 | 5.66 |
| — perpendicular to face grain | 3.20 | 4.04 | 3.99 | 3.99 | 3.55 | 4.58 | 3.20 | 3.99 |
| Compression: | | | | | | | | |
| — parallel to face grain | 8.02 | 8.02 | 8.18 | 7.09 | 8.32 | 6.80 | 7.49 | 8.57 |
| — perpendicular to face grain | 4.19 | 5.32 | 5.22 | 5.22 | 4.68 | 6.00 | 4.19 | 5.22 |
| Bearing: | | | | | | | | |
| — on face | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 |
| Rolling shear in plane of plies: | | | | | | | | |
| — in face veneer<br>— in back veneer<br>— at first glueline | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 | 0.39 | 0.51 | 0.51 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.57 | 0.44 | 0.55 | 0.44 | 0.58 | 0.44 | 0.59 | 0.55 |
| — face grain perpendicular to span | 0.46 | 0.48 | 0.48 | 0.51 | 0.42 | 0.53 | 0.44 | 0.44 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 4 825 | 5 005 | 4 605 | 4 630 | 4 745 | 4 395 | 4 400 | 4 705 |
| — face grain perpendicular to span | 1 400 | 1 395 | 1 805 | 1 535 | 1 545 | 1 880 | 1 550 | 1 745 |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 3 125 | 3 125 | 3 180 | 2 760 | 3 240 | 2 650 | 2 900 | 3 335 |
| — perpendicular to face grain | 1 740 | 2 195 | 2 160 | 2 160 | 1 940 | 2 495 | 1 735 | 2 170 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 250 | 250 | 245 | 245 | 245 | 245 | 245 | 245 |

**Table 46 — Grade stresses and moduli for service classes 1 and 2 for Canadian Douglas fir plywood: good two sides and good one side grades: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 14 (5) | 14 (6) | 17 (5) | 17 (6) | 17 (7) | 19 (5) | 19 (6) | 19 (7) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 8.21 | 9.33 | 7.34 | 7.78 | 8.62 | 8.55 | 7.22 | 7.79 |
| — face grain perpendicular to span | 5.82 | 6.57 | 6.45 | 6.23 | 6.30 | 8.27 | 6.21 | 6.25 |
| Tension: | | | | | | | | |
| — parallel to face grain | 4.28 | 5.79 | 4.09 | 4.77 | 4.77 | 4.70 | 4.59 | 4.26 |
| — perpendicular to face grain | 3.24 | 3.24 | 3.89 | 2.67 | 4.01 | 4.48 | 2.39 | 3.58 |
| Compression: | | | | | | | | |
| — parallel to face grain | 6.46 | 8.73 | 6.18 | 7.19 | 7.19 | 7.09 | 6.92 | 6.44 |
| — perpendicular to face grain | 4.26 | 4.26 | 5.11 | 3.51 | 5.26 | 5.88 | 3.14 | 4.70 |
| Bearing: | | | | | | | | |
| — on face | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 |
| Rolling shear in plane of plies: | | | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glue line | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.57 | 0.58 | 0.44 | 0.45 | 0.52 | 0.50 | 0.45 | 0.53 |
| — face grain perpendicular to span | 0.37 | 0.31 | 0.30 | 0.31 | 0.44 | 0.31 | 0.31 | 0.47 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 1.58 | 1.58 | 1.56 | 1.56 | 1.56 | 1.57 | 1.55 | 1.55 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 3 425 | 3 695 | 3 035 | 3 140 | 3 480 | 3 345 | 2 915 | 3 175 |
| — face grain perpendicular to span | 1 435 | 1 745 | 1 615 | 1 705 | 1 720 | 2 360 | 1 770 | 1 785 |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 2 510 | 3 395 | 2 400 | 2 795 | 2 795 | 2 755 | 2 690 | 2 500 |
| — perpendicular to face grain | 1 765 | 1 765 | 2 120 | 1 455 | 2 180 | 2 440 | 1 300 | 1 950 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 235 | 235 | 235 | 235 | 235 | 235 | 230 | 230 |

**Table 47** — *Text deleted*

**Table 48** — *Text deleted*

**Table 49 — Grade stresses and moduli for service classes 1 and 2 for Finnish birch plywood 1.4 mm veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.5 (5) | 9 (7) | 12 (9) | 15 (11) | 18 (13) | 21 (15) | 24 (17) | 27 (19) | 30 (21) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | |
| — face grain parallel to span | 20.68 | 19.60 | 18.32 | 17.93 | 17.58 | 17.24 | 17.14 | 16.94 | 16.79 |
| — face grain perpendicular to span | 10.54 | 12.46 | 13.59 | 13.79 | 13.99 | 14.23 | 14.28 | 14.33 | 14.43 |
| Tension: | | | | | | | | | |
| — parallel to face grain | 20.78 | 19.75 | 19.16 | 18.86 | 18.62 | 18.42 | 18.32 | 18.22 | 18.12 |
| — perpendicular to face grain | 15.17 | 15.86 | 16.20 | 16.45 | 16.60 | 16.70 | 16.79 | 16.84 | 16.89 |
| Compression: | | | | | | | | | |
| — parallel to face grain | 10.34 | 10.00 | 9.80 | 9.70 | 9.60 | 9.55 | 9.50 | 9.46 | 9.46 |
| — perpendicular to face grain | 8.08 | 8.42 | 8.62 | 8.72 | 8.82 | 8.86 | 8.91 | 8.91 | 8.96 |
| Bearing: | | | | | | | | | |
| — on face | 3.93 | 3.93 | 3.93 | 3.93 | 3.93 | 3.93 | 3.93 | 3.93 | 3.93 |
| Rolling shear: | | | | | | | | | |
| — in face veneer | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 |
| — in back veneer | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 |
| — at first glueline | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 |
| Transverse shear: | | | | | | | | | |
| — bending: | | | | | | | | | |
| — face grain parallel to span | 1.41 | 1.32 | 1.37 | 1.30 | 1.32 | 1.28 | 1.30 | 1.27 | 0.27 |
| — face grain perpendicular to span | 0.90 | 1.17 | 1.12 | 1.19 | 1.17 | 1.19 | 1.18 | 1.21 | 0.21 |
| Panel shear: | | | | | | | | | |
| — parallel and perpendicular to face grain | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 |
| Modulus of elasticity in bending: | | | | | | | | | |
| — face grain parallel to span | 5 850 | 5 200 | 4 900 | 4 750 | 4 600 | 4 500 | 4 450 | 4 400 | 4 350 |
| — face grain perpendicular to span | 2 150 | 2 800 | 3 100 | 3 300 | 3 400 | 3 490 | 3 550 | 3 600 | 3 650 |
| Modulus of elasticity in tension and compression: | | | | | | | | | |
| — parallel to face grain | 4 500 | 4 350 | 4 250 | 4 200 | 4 200 | 4 150 | 4 150 | 4 150 | 4 100 |
| — perpendicular to face grain | 3 500 | 3 650 | 3 750 | 3 800 | 3 800 | 3 850 | 3 850 | 3 800 | 3 900 |
| Shear modulus (for panel shear): | | | | | | | | | |
| — parallel and perpendicular to face grain | 320 | 320 | 320 | 320 | 320 | 320 | 320 | 320 | 320 |

**Table 50 — Grade stresses and moduli for service classes 1 and 2 for Finnish conifer plywood 1.4 mm veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.5 (5) | 9 (7) | 12 (9) | 15 (11) | 18 (13) | 21 (15) | 24 (17) | 27 (19) | 30 (21) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | |
| — face grain parallel to span | 12.41 | 11.08 | 10.44 | 10.05 | 9.80 | 9.65 | 9.50 | 9.41 | 9.36 |
| — face grain perpendicular to span | 6.06 | 7.04 | 7.39 | 7.58 | 7.68 | 7.73 | 7.78 | 7.83 | 7.83 |
| Tension: | | | | | | | | | |
| — parallel to face grain | 9.50 | 9.01 | 8.77 | 8.62 | 8.52 | 8.42 | 8.37 | 8.32 | 8.27 |
| — perpendicular to face grain | 6.94 | 7.24 | 7.44 | 7.53 | 7.58 | 7.63 | 7.68 | 7.68 | 7.73 |
| Compression: | | | | | | | | | |
| — parallel to face grain | 8.37 | 8.13 | 7.93 | 7.58 | 7.58 | 7.73 | 7.73 | 7.68 | 7.68 |
| — perpendicular to face grain | 6.50 | 6.80 | 6.94 | 7.09 | 7.09 | 7.14 | 7.19 | 7.24 | 7.24 |
| Bearing: | | | | | | | | | |
| — on face | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 |
| Rolling shear: | | | | | | | | | |
| — in face veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — in back veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — at first glueline | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Transverse shear: | | | | | | | | | |
| — bending: | | | | | | | | | |
| — face grain parallel to span | 0.98 | 0.88 | 0.93 | 0.86 | 0.86 | 0.82 | 0.84 | 0.98 | 0.98 |
| — face grain perpendicular to span | 0.54 | 0.74 | 0.74 | 0.77 | 0.75 | 0.75 | 0.77 | 0.98 | 0.98 |
| Panel shear: | | | | | | | | | |
| — parallel and perpendicular to face grain | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 |
| Modulus of elasticity in bending: | | | | | | | | | |
| — face grain parallel to span | 4 600 | 4 100 | 3 850 | 3 650 | 3 650 | 3 550 | 3 500 | 3 450 | 3 450 |
| — face grain perpendicular to span | 1 700 | 2 200 | 2 450 | 2 700 | 2 700 | 2 750 | 2 800 | 2 850 | 2 850 |
| Modulus of elasticity in tension and compression: | | | | | | | | | |
| — parallel to face grain | 3 550 | 3 450 | 3 350 | 3 300 | 3 300 | 3 300 | 3 250 | 3 350 | 3 250 |
| — perpendicular to face grain | 2 750 | 2 900 | 2 950 | 3 000 | 3 000 | 3 050 | 3 050 | 3 050 | 3 050 |
| Shear modulus (for panel shear): | | | | | | | | | |
| — parallel and perpendicular to face grain | 270 | 270 | 270 | 270 | 270 | 270 | 270 | 270 | 270 |

**Table 51 — Grade stresses and moduli for service classes 1 and 2 for Finnish conifer plywood thick veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of veneers in parentheses) mm | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 (3) | 9 (5) | 12 (4) | 12 (5) | 12 (7) | 15 (5) | 15 (7) | 15 (9) | 18 (6) | 18 (7) | 18 (9) | 18 (11) | 21 (7) | 21 (9) | 21 (11) | 24 (8) | 24 (9) | 24 (11) | 24 (13) | 27 (9) | 27 (11) | 30 (10) | 30 (13) |
| | Grade stress or modulus N/mm² | | | | | | | | | | | | | | | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | | | | | | | | | | | | | | | |
| — face grain parallel to span | 14.13 | 10.19 | 12.68 | 11.24 | 10.79 | 11.33 | 8.67 | 8.77 | 10.61 | 10.06 | 7.88 | 10.54 | 9.29 | 8.57 | 7.68 | 10.10 | 9.37 | 7.63 | 11.08 | 9.55 | 7.27 | 7.39 | 6.38 |
| — face grain perpendicular to span | 1.42 | 6.21 | 4.02 | 5.63 | 6.85 | 5.48 | 7.09 | 7.78 | 6.08 | 6.39 | 7.88 | 6.94 | 6.27 | 7.24 | 7.98 | 6.10 | 6.73 | 7.93 | 6.16 | 6.60 | 8.21 | 8.89 | 9.10 |
| Tension: | | | | | | | | | | | | | | | | | | | | | | | |
| — parallel to face grain | 5.74 | 7.19 | 4.24 | 5.15 | 9.06 | 5.18 | 7.09 | 7.19 | 5.83 | 4.94 | 6.65 | 8.86 | 4.73 | 6.94 | 6.35 | 6.60 | 4.93 | 6.60 | 8.47 | 4.85 | 4.36 | 4.84 | 4.00 |
| — perpendicular to face grain | 2.74 | 7.49 | 4.63 | 3.72 | 5.91 | 3.67 | 6.60 | 7.93 | 3.04 | 3.93 | 7.34 | 6.40 | 3.89 | 6.55 | 7.93 | 2.26 | 3.94 | 7.19 | 5.81 | 4.02 | 4.50 | 4.02 | 4.87 |
| Compression: | | | | | | | | | | | | | | | | | | | | | | | |
| — parallel to face grain | 9.56 | 6.35 | 7.07 | 8.58 | 8.42 | 8.64 | 6.55 | 6.55 | 9.71 | 8.23 | 6.11 | 8.27 | 7.89 | 6.50 | 5.81 | 11.01 | 8.21 | 6.16 | 8.08 | 8.09 | 7.27 | 8.07 | 6.66 |
| — perpendicular to face grain | 4.57 | 7.29 | 7.71 | 6.20 | 5.52 | 6.12 | 6.45 | 7.58 | 5.07 | 6.55 | 7.19 | 6.01 | 6.49 | 6.40 | 7.73 | 3.77 | 6.57 | 6.99 | 4.97 | 6.69 | 7.50 | 6.71 | 8.12 |
| Bearing: | | | | | | | | | | | | | | | | | | | | | | | |
| — on face | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 |
| Rolling shear: | | | | | | | | | | | | | | | | | | | | | | | |
| — in face veneer | 0.44 | 0.79 | 0.39 | 0.44 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.79 | 0.39 | 0.44 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glue line | 0.44 | 0.79 | 0.39 | 0.44 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.79 | 0.79 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | | | | | | | | | | | | | | | | |
| — bending: | 0.48 | 1.05 | 0.46 | 0.52 | 0.88 | 0.52 | 0.86 | 0.86 | 0.49 | 0.48 | 0.86 | 0.86 | 0.47 | 0.82 | 0.82 | 0.45 | 0.48 | 0.84 | 0.84 | 0.49 | 0.44 | 0.38 | 0.45 |
| — face grain parallel to span | 0.14 | 0.63 | 0.21 | 0.30 | 0.75 | 0.30 | 0.72 | 0.72 | 0.32 | 0.38 | 0.75 | 0.75 | 0.38 | 0.68 | 0.68 | — | 0.39 | 0.74 | 0.74 | 0.38 | 0.45 | 0.54 | 0.44 |
| — face grain perpendicular to span | 1.72 | 3.74 | 1.72 | 1.72 | 3.74 | 1.72 | 3.74 | 3.74 | 1.72 | 1.72 | 3.74 | 3.74 | 1.72 | 3.74 | 3.74 | 1.72 | 1.72 | 3.74 | 3.74 | 1.72 | 1.72 | 1.72 | 1.72 |
| Modulus of elasticity in bending: | | | | | | | | | | | | | | | | | | | | | | | |
| — face grain parallel to span | 5 736 | 3 800 | 5 148 | 4 562 | 4 100 | 4 600 | 3 250 | 3 600 | 4 307 | 4 085 | 2 950 | 3 900 | 3 773 | 3 200 | 2 850 | 4 103 | 3 804 | 2 850 | 4 100 | 3 876 | 2 951 | 3 002 | 2 592 |
| — face grain perpendicular to span | 178 | 2 550 | 852 | 1 438 | 2 200 | 1 382 | 3 050 | 2 700 | 1 693 | 1 915 | 3 350 | 2 400 | 1 862 | 3 100 | 3 450 | 1 897 | 2 196 | 3 450 | 2 200 | 2 124 | 3 049 | 2 998 | 3 408 |
| Modulus of elasticity in tension and compression: | | | | | | | | | | | | | | | | | | | | | | | |
| — parallel to face grain | 3 882 | 2 700 | 2 870 | 3 484 | 3 950 | 3 506 | 3 100 | 2 750 | 3 943 | 3 341 | 2 750 | 3 750 | 3 204 | 3 100 | 2 450 | 4 468 | 3 333 | 2 800 | 4 000 | 3 283 | 2 953 | 3 277 | 2 704 |
| — perpendicular to face grain | 1 857 | 3 650 | 3 130 | 2 516 | 2 350 | 2 483 | 3 200 | 3 550 | 2 057 | 2 659 | 3 600 | 2 550 | 2 634 | 3 200 | 3 850 | 1 532 | 2 667 | 3 500 | 2 300 | 2 717 | 3 047 | 2 723 | 3 296 |
| Shear modulus (for panel shear): | | | | | | | | | | | | | | | | | | | | | | | |
| — parallel to and perpendicular to face grain | 175 | 270 | 175 | 175 | 270 | 175 | 270 | 270 | 175 | 175 | 270 | 270 | 175 | 270 | 270 | 175 | 175 | 270 | 270 | 175 | 175 | 175 | 175 |

**Table 52 — Grade stresses and moduli for service classes 1 and 2 for Finnish combi plywood 1.4 mm veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.5 (5) | 9 (7) | 12 (9) | 15 (11) | 18 (13) | 21 (15) | 24 (17) | 27 (19) | 30 (21) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | |
| — face grain parallel to span | 20.68 | 18.71 | 17.63 | 17.09 | 16.55 | 16.35 | 15.96 | 15.86 | 15.66 |
| — face grain perpendicular to span | 6.25 | 12.41 | 13.49 | 13.64 | 13.84 | 14.13 | 14.13 | 14.23 | 14.28 |
| Tension: | | | | | | | | | |
| — parallel to face grain | 20.78 | 13.99 | 12.61 | 11.72 | 11.13 | 10.69 | 10.34 | 10.10 | 9.90 |
| — perpendicular to face grain | 7.24 | 15.86 | 16.20 | 16.45 | 16.60 | 16.70 | 16.79 | 16.84 | 16.89 |
| Compression: | | | | | | | | | |
| — parallel to face grain | 10.15 | 9.01 | 8.72 | 8.52 | 8.37 | 8.27 | 8.18 | 8.13 | 8.08 |
| — perpendicular to face grain | 6.75 | 8.32 | 8.47 | 8.57 | 8.67 | 8.72 | 8.72 | 8.77 | 8.77 |
| Bearing: | | | | | | | | | |
| — on face | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Rolling shear: | | | | | | | | | |
| — in face veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — in back veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — at first glueline | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Transverse shear: | | | | | | | | | |
| — bending: | | | | | | | | | |
| — face grain parallel to span | 0.75 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| — face grain perpendicular to span | 0.92 | 0.56 | 0.53 | 0.59 | 0.55 | 0.58 | 0.56 | 0.58 | 0.58 |
| Panel shear: | | | | | | | | | |
| — parallel and perpendicular to face grain | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 |
| Modulus of elasticity in bending: | | | | | | | | | |
| — face grain parallel to span | 5 850 | 5 050 | 4 650 | 4 400 | 4 200 | 4 050 | 3 950 | 3 850 | 3 800 |
| — face grain perpendicular to span | 1 700 | 2 800 | 3 100 | 3 250 | 3 400 | 3 500 | 3 550 | 3 600 | 3 650 |
| Modulus of elasticity in tension and compression: | | | | | | | | | |
| — parallel to face grain | 4 500 | 3 850 | 3 700 | 3 600 | 3 500 | 3 450 | 3 400 | 3 400 | 3 350 |
| — perpendicular to face grain | 2 650 | 3 650 | 3 750 | 3 800 | 3 800 | 3 850 | 3 850 | 3 800 | 3 900 |
| Shear modulus (for panel shear): | | | | | | | | | |
| — parallel and perpendicular to face grain | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 |

**Table 53 — Grade stresses and moduli for service classes 1 and 2 for Finnish combi plywood thick veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 12 (7) | 15 (9) | 18 (11) | 21 (11) | 21 (13) | 24 (13) | 24 (15) | 27 (17) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 17.48 | 17.63 | 17.29 | 17.04 | 16.89 | 17.14 | 16.74 | 17.53 |
| — face grain perpendicular to span | 11.52 | 12.07 | 12.31 | 11.08 | 12.85 | 11.47 | 12.95 | 12.90 |
| Tension: | | | | | | | | |
| — parallel to face grain | 12.71 | 12.26 | 11.47 | 10.79 | 11.08 | 10.64 | 10.69 | 10.39 |
| — perpendicular to face grain | 12.26 | 13.94 | 13.99 | 12.07 | 14.82 | 14.77 | 14.87 | 14.92 |
| Compression: | | | | | | | | |
| — parallel to face grain | 9.06 | 8.96 | 8.82 | 8.67 | 8.67 | 8.67 | 8.57 | 8.52 |
| — perpendicular to face grain | 6.45 | 7.29 | 7.29 | 6.30 | 7.73 | 6.65 | 7.78 | 7.78 |
| Bearing: | | | | | | | | |
| — on face | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Rolling shear: | | | | | | | | |
| — in face veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — in back veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — at first glueline | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| — face grain perpendicular to span | 0.56 | 0.56 | 0.62 | 0.55 | 0.55 | 0.56 | 0.56 | 0.58 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 4 900 | 4 650 | 4 450 | 4 600 | 4 300 | 4 450 | 4 200 | 4 100 |
| — face grain perpendicular to span | 2 800 | 2 950 | 3 050 | 2 800 | 3 200 | 2 950 | 3 250 | 3 300 |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 2 850 | 3 200 | 3 200 | 2 800 | 3 400 | 2 950 | 3 450 | 3 450 |
| — perpendicular to face grain | 4 400 | 4 050 | 4 000 | 4 300 | 3 800 | 4 150 | 3 750 | 3 750 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 |

**Table 54 — Grade stresses and moduli for service classes 1 and 2 for Finnish mirror plywood 1.4 mm veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.5 (5) | 9 (7) | 12 (9) | 15 (11) | 18 (13) | 21 (15) | 24 (17) | 27 (19) | 30 (21) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | | |
| Extreme fibre in bending: | | | | | | | | | |
| — face grain parallel to span | 20.68 | 19.45 | 18.17 | 17.78 | 17.48 | 17.09 | 16.94 | 16.74 | 16.60 |
| — face grain perpendicular to span | 6.25 | 7.24 | 7.58 | 7.63 | 7.78 | 7.83 | 7.88 | 7.88 | 7.88 |
| Tension: | | | | | | | | | |
| — parallel to face grain | 20.78 | 19.75 | 19.21 | 18.86 | 18.62 | 18.47 | 18.32 | 18.22 | 18.12 |
| — perpendicular to face grain | 6.94 | 7.24 | 7.39 | 7.49 | 7.58 | 7.63 | 7.68 | 7.68 | 7.73 |
| Compression: | | | | | | | | | |
| — parallel to face grain | 10.15 | 9.80 | 9.60 | 9.50 | 9.41 | 9.36 | 9.31 | 9.31 | 9.26 |
| — perpendicular to face grain | 6.75 | 6.99 | 7.14 | 7.24 | 7.29 | 7.34 | 7.39 | 7.44 | 7.44 |
| Bearing: | | | | | | | | | |
| — on face | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Rolling shear: | | | | | | | | | |
| — in face veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — in back veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — at first glueline | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Transverse shear: | | | | | | | | | |
| — bending: | | | | | | | | | |
| — face grain parallel to span | 0.75 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| — face grain perpendicular to span | 0.92 | 0.56 | 0.53 | 0.59 | 0.55 | 0.58 | 0.56 | 0.58 | 0.59 |
| Panel shear: | | | | | | | | | |
| — parallel and perpendicular to face grain | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 |
| Modulus of elasticity in bending: | | | | | | | | | |
| — face grain parallel to span | 5 850 | 5 250 | 4 900 | 4 750 | 4 600 | 4 500 | 4 450 | 4 400 | 4 350 |
| — face grain perpendicular to span | 1 700 | 2 200 | 2 450 | 2 600 | 2 700 | 2 750 | 2 800 | 2 850 | 2 850 |
| Modulus of elasticity in tension and compression: | | | | | | | | | |
| — parallel to face grain | 4 500 | 4 350 | 4 300 | 4 250 | 4 200 | 4 150 | 4 150 | 4 150 | 4 100 |
| — perpendicular to face grain | 2 750 | 2 850 | 2 950 | 3 000 | 3 000 | 3 000 | 3 050 | 3 050 | 3 050 |
| Shear modulus (for panel shear): | | | | | | | | | |
| — parallel and perpendicular to face grain | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 |

**Table 55 — Grade stresses and moduli for service classes 1 and 2 for Finnish twin plywood 1.4 mm veneer: sanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 9 (7) | 12 (9) | 15 (11) | 18 (13) | 21 (15) | 24 (17) | 27 (19) | 30 (21) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 18.47 | 17.43 | 16.84 | 16.35 | 16.10 | 15.76 | 15.66 | 15.41 |
| — face grain perpendicular to span | 7.19 | 7.49 | 7.63 | 7.73 | 7.78 | 7.83 | 7.83 | 7.83 |
| Tension: | | | | | | | | |
| — parallel to face grain | 14.04 | 12.61 | 11.72 | 11.13 | 10.69 | 10.34 | 10.10 | 9.90 |
| — perpendicular to face grain | 7.24 | 7.39 | 7.49 | 7.58 | 7.63 | 7.68 | 7.68 | 7.73 |
| Compression: | | | | | | | | |
| — parallel to face grain | 8.86 | 8.52 | 8.32 | 8.18 | 8.08 | 8.03 | 7.93 | 7.88 |
| — perpendicular to face grain | 6.89 | 7.04 | 7.09 | 7.14 | 7.19 | 7.24 | 7.24 | 7.29 |
| Bearing: | | | | | | | | |
| — on face | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 | 1.88 |
| Rolling shear: | | | | | | | | |
| — in face veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — in back veneer | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| — at first glueline | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.88 | 0.93 | 0.86 | 0.86 | 0.82 | 0.84 | 0.81 | 0.84 |
| — face grain perpendicular to span | 0.74 | 0.74 | 0.77 | 0.75 | 0.75 | 0.77 | 0.77 | 0.74 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 | 4.43 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 5 050 | 4 650 | 4 400 | 4 200 | 4 050 | 3 950 | 3 850 | 3 800 |
| — face grain perpendicular to span | 2 200 | 2 450 | 2 600 | 2 700 | 2 750 | 2 800 | 2 850 | 2 850 |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 3 850 | 3 700 | 3 600 | 3 500 | 3 450 | 3 450 | 3 400 | 3 350 |
| — perpendicular to face grain | 2 850 | 2 950 | 3 000 | 3 000 | 3 050 | 3 050 | 3 050 | 3 050 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 285 | 285 | 285 | 285 | 285 | 285 | 285 | 285 |

**Table 56 — Grade stresses and moduli for service classes 1 and 2 for Swedish softwood plywood: P 30. Spruce: unsanded**

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 (3) | 9 (3) | 12 (5) | 15 (5) | 18 (5) | 18 (7) | 21 (7) | 24 (9) |
| | Grade stress or modulus $N/mm^2$ | | | | | | | |
| Extreme fibre in bending: | | | | | | | | |
| — face grain parallel to span | 13.69 | 13.69 | 11.33 | 11.33 | 11.87 | 9.65 | 10.49 | 10.64 |
| — face grain perpendicular to span | 2.41 | 3.55 | 5.61 | 5.91 | 6.21 | 5.91 | 7.34 | 6.11 |
| Tension: | | | | | | | | |
| — parallel to face grain | 8.22 | 8.22 | 7.39 | 7.39 | 7.19 | 6.25 | 7.04 | 7.58 |
| — perpendicular to face grain | 4.88 | 4.88 | 5.91 | 5.91 | 5.91 | 7.24 | 6.35 | 5.61 |
| Compression: | | | | | | | | |
| — parallel to face grain | 8.22 | 8.22 | 7.39 | 7.39 | 7.19 | 6.25 | 7.04 | 7.58 |
| — perpendicular to face grain | 4.88 | 4.88 | 5.91 | 5.91 | 5.91 | 7.24 | 6.35 | 5.61 |
| Bearing: | | | | | | | | |
| — on face | 2.39 | 2.39 | 2.39 | 2.39 | 2.39 | 2.39 | 2.39 | 2.39 |
| Rolling shear: | | | | | | | | |
| — in face veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — in back veneer | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| — at first glueline | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Transverse shear: | | | | | | | | |
| — bending: | | | | | | | | |
| — face grain parallel to span | 0.48 | 0.48 | 0.54 | 0.54 | 0.56 | 0.56 | 0.50 | 0.50 |
| — face grain perpendicular to span | 0.80 | 0.85 | 0.31 | 0.31 | 0.31 | 0.31 | 0.37 | 0.38 |
| Panel shear: | | | | | | | | |
| — parallel and perpendicular to face grain | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 |
| Modulus of elasticity in bending: | | | | | | | | |
| — face grain parallel to span | 5 500 | 5 500 | 4 600 | 4 600 | 4 850 | 3 900 | 4 750 | 4 350 |
| — face grain perpendicular to span | 1 000 | 1 450 | 2 300 | 2 400 | 2 500 | 1 300 | 3 000 | 2 500 |

**Table 56 — Grade stress and moduli for service classes 1 and 2 for Swedish softwood plywood: P 30. Spruce: unsanded** *(continued)*

| Type and direction of stress and modulus | Nominal thickness (with number of plies in parentheses) mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 (3) | 9 (3) | 12 (5) | 15 (5) | 18 (5) | 18 (7) | 21 (7) | 24 (9) |
| | Grade stress or modulus N/mm$^2$ | | | | | | | |
| Modulus of elasticity in tension and compression: | | | | | | | | |
| — parallel to face grain | 4 000 | 4 000 | 3 600 | 3 600 | 3 500 | 3 050 | 3 450 | 3 700 |
| — perpendicular to face grain | 2 000 | 2 000 | 2 400 | 2 400 | 2 400 | 2 950 | 2 600 | 2 300 |
| Shear modulus (for panel shear): | | | | | | | | |
| — parallel and perpendicular to face grain | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |

# Section 5. Panel products other than plywood

## 5.1 General

This section gives recommendations on the use of wood fibreboard, wood particleboard, medium density fibreboard (MDF), oriented strand boards (OSB), and cement bonded particleboards, for grades and exposure classes given in Table 57.

## 5.2 Section properties

Section properties should be based on the actual thickness if known, or if not, on the minimum thickness specified in the relevant British or European Standard.

## 5.3 Strength and elastic moduli

Characteristic strength and elastic moduli should be obtained, or derived by test, according to BS EN 12369 for the wood panels stated therein.

Characteristic strength values are defined as the population 5-percentile value obtained from tests with a duration of 300 s using test pieces at an equilibrium moisture content resulting from a temperature of 20 °C and a relative humidity of 65 %.

Characteristic moduli values are defined as either the 5-percentile value or the mean value, under the same test conditions as defined above.

Characteristic strength values should be converted into grade strength values for the permissible stress basis of design by:

$$X_d = k_{mod} X_k / (1.35 \gamma_M)$$

where

$X_d$ is the grade strength value;

$X_k$ is the characteristic strength value;

$k_{mod}$ is the modification factor for strength and service class given in Table 57;

$\gamma_M$ is the material partial factor = 1.3 for panel products other than plywood.

When a modification factor, $k_{mod}$, greater than unity is used in accordance with this clause, the design should be checked to ensure that the permissible stresses are not exceeded for any other condition of loading that might be relevant.

Characteristic moduli values should be converted into grade moduli values for the permissible stress basis of design by:

$$E_d = E_k / (1 + k_{def})$$

where

$E_d$ is the grade modulus value;

$E_k$ is the characteristic modulus value (mean or minimum value as appropriate);

$k_{def}$ is the modification factor for creep deformation and service class given in Table 58.

The deflections or deformations of a structural member subject to a combination of loads of different duration should be determined by considering the load in each category as acting separately, and calculating the deflections or deformations induced by each, using the appropriate modulus value. The total deflections or deformations should be taken as the sum of those caused by the individual loads.

**Table 57 — Modification factor, $k_{mod}$, for duration of loading and service class for panel products other than plywood**

| Duration of loading | Service class | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| **Particleboards to BS EN 312-6 (P6), BS EN 312-7 (P7), OSB to BS EN 300:1997, Grades 3 and 4** | | | |
| Long-term | 0.40 | 0.30 | — |
| Medium-term | 0.82 | 0.64 | — |
| Test duration | 1.02 | 0.82 | — |
| Short-term | 1.06 | 0.85 | — |
| Very short-term | 1.07 | 0.87 | — |
| **Particleboard to BS EN 312-4 [a] (P4), BS EN 312-5 (P5), OSB to BS EN 300:1997, Grade 2 [a] Fibreboard to BS EN 622-5 (MDF) (hardboards)** | | | |
| Long-term | 0.30 | 0.20 | — |
| Medium-term | 0.76 | 0.53 | — |
| Test duration | 0.99 | 0.72 | — |
| Short-term | 1.05 | 0.76 | — |
| Very short-term | 1.07 | 0.77 | — |
| **Fibreboard to BS EN 622-2 (hardboard), BS EN 622-3 (mediumboard)** | | | |
| Long-term | 0.20 | — | — |
| Medium-term | 0.72 | — | — |
| Test duration | 0.97 | — | — |
| Short-term | 1.04 | — | — |
| Very short-term | 1.06 | — | — |

[a] Not to be used in Service class 2.

**Table 58 — Modification factor, $k_{def}$, for elastic or shear modulus for panel products other than plywood**

| Duration of loading | Service class | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| **Particleboards to BS EN 312-6 [a], BS EN 312-7, OSB to BS EN 300:1997, Grades 3 and 4** | | | |
| Long-term | 1.50 | 2.25 | — |
| Medium-term | 0.22 | 0.51 | — |
| Test duration | 0.00 | 0.00 | — |
| Short-term | 0.00 | 0.00 | — |
| Very short-term | 0.00 | 0.00 | — |
| **Particleboard to BS EN 312-4 [a], BS EN 314-5, OSB to BS EN 300:1997, Grade 2 [a] Fibreboard to BS EN 622-5 (hardboards)** | | | |
| Long-term | 2.25 | 3.00 | — |
| Medium-term | 0.34 | 0.67 | — |
| Test duration | 0.00 | 0.00 | — |
| Short-term | 0.00 | 0.00 | — |
| Very short-term | 0.00 | 0.00 | — |
| **Fibreboard to BS EN 622-2 (hardboard), BS EN 622-3 (mediumboard)** | | | |
| Long-term | 3.00 | — | — |
| Medium-term | 0.64 | — | — |
| Test duration | 0.00 | — | — |
| Short-term | 0.00 | — | — |
| Very short-term | 0.00 | — | — |

[a] Not to be used in Service class 2.

## 5.4 Panel products for roof and floor decking

The design of panel products for decking on roofs and floors should be determined:

a) in accordance with BS 7916 for appropriate grades of particleboards, MDF, OSB and cement bonded particleboards and their conditions of use specified therein; or

b) by calculation using grade stresses and moduli; or

c) where used for buildings, by testing on samples of typical roof or floor assemblies with the product supported on joists, under impact and concentrated static loads (of the appropriate contact area) in accordance with BS EN 1195 (see **8.9**) to satisfy the performance specification and requirements in BS EN 12871 and **8.9**. The application of panel products for these purposes should conform to BS 7916.

The requirement in BS EN 12871 to verify the design by calculation for uniformly distributed loading need not be made where:

— the specified imposed loading is in accordance with BS 6399 but excluding loading for vehicle traffic areas;

— the ratio of uniformly distributed load (in $kN/m^2$) to the related concentrated load (in kN) does not exceed 1.5;

— the maximum span of the panel product in the roof or floor decking is not more than 1.00 m.

NOTE This method of design does not apply to garage and vehicle traffic areas and roofs for special services such as helicopter landings.

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# Section 6. Joints

## 6.1 General

This section is applicable to nailed, screwed, bolted, dowelled, connectored and glued joints. However, not all fasteners dealt with in this section are covered by British Standards. When the British Standards listed in the list of references are appropriate, the fasteners should conform to those standards.

Annex G sets out the basis upon which the tabulated lateral loads in this section were derived. These formulae may be used in lieu of the tabulated data if preferred, and may be used for other material/fastener applications.

The recommendations of this section do not apply to punched metal plate fasteners with or without integral teeth.

Joints should be so designed that the loads induced in each fastener or timber connector unit by the design loads appropriate to the structure should not exceed the permissible values determined in accordance with this section.

Generally, basic loads for single fasteners subjected to long-term loading in the dry exposure condition are tabulated in this section. Permissible loads for other conditions, type of loading and joint geometry should be determined by multiplying the basic loads by the appropriate modification factors, also given in this section. For bolted or dowelled joints, long-, medium- and short-term permissible loads are tabulated directly.

For the purpose of design, joint loads are tabulated for the strength classes given in **2.6**. The individual species and grades which qualify for a particular strength class can be obtained by reference to Table 2, Table 3, Table 4, Table 5 and Table 6.

For the purposes of designing joints in glued laminated timber, tabulated values should be taken for the strength class of timber from which the glued laminated timber was made.

Under some conditions, metal fasteners may become corroded through contact with treated timber. The manufacturer of the treatment chemical should therefore be consulted about the possibility of interactions. Reference should be made also to part 5 of this British Standard.

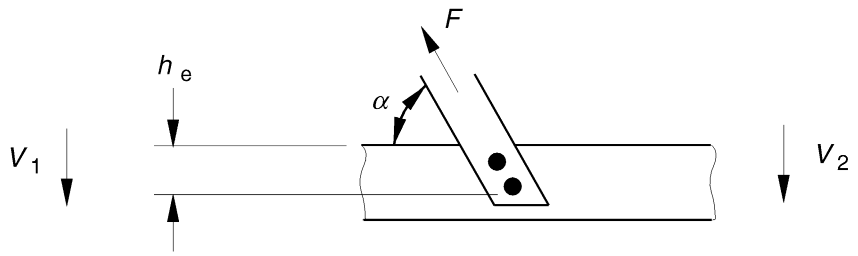
The effective cross-section of a jointed member should be used when calculating its strength. The method of determining the effective cross-section is given in the appropriate clauses for each type of fastener. In addition, it should be shown that the shear stress condition shown in Figure 6 is satisfied in the jointed member.

If the load on a joint is carded by more than one type of fastener, due account should be taken of the relative stiffnesses. Glue and mechanical fasteners have very different stiffness properties and should not be assumed to act in unison.

If the line of action of a force in a member does not pass through the centroid of the group of fasteners transmitting load to it, account should be taken of the stresses and loads due to the secondary moments induced by the eccentricity (see also **1.6.11.1** and **1.6.11.2**).

Where wide members are involved, regard should be paid to the possible splitting of the member if its moisture content is reduced after the joint is made.

The fastener spacings, end distances and edge distances given in this section refer to distances from fastener centre-lines.




$V \leq \frac{2}{3}\tau_{adm}h_e t$

where

| | |
|---|---|
| $V$ | is the maximum shear force per member at the joint ($V_1 + V_2 = F_{sin}\ \alpha$); |
| $h_e$ | is the distance from the loaded edge to the farthest fastener; |
| $\tau_{adm}$ | is the permissible shear stress; |
| $t$ | is the member thickness. |

**Figure 6 — Shear stress in the jointed timber**

## 6.2 Joint slip

In certain structures, joint slip may have an appreciable effect on overall deflections, and due allowance may need to be made. Should this be considered appropriate, the slip moduli, in newtons per millimetre per fastener per shear plane, given in Table 59 may be used.

The slip per fastener per shear plane, $u$, in millimetres, may then be taken as:

$$u = \frac{F}{K_{ser}}$$

where

$F$ is the applied load per fastener per shear plane, in newtons.

For bolted joints an additional 1 mm should be added at each joint to allow for take-up of bolt-hole tolerances.

NOTE The final slip following medium- or long-term loading may be considerably greater than the slip calculated as above, particularly in conditions of fluctuating moisture content.

## 6.3 Anti-corrosion treatment

The loads specified for nails, screws, bolts and dowels apply to fasteners that are not treated against corrosion. Some forms of anti-corrosion treatment may affect fastener performance.

The loads specified for timber connectors apply to fasteners that are treated against corrosion.

Fasteners used in wet timber or in timber which will be exposed to the wet exposure condition should be non-corrodible or be treated by an anti-corrosive process.

## 6.4 Nailed joints

### 6.4.1 General

The recommendations contained in **6.4** are applicable to nails which conform to BS 1202-1.

For the loads given here for nails to be valid, the steel wire from which the nails are produced should have a minimum ultimate tensile strength of 600 N/mm².

A nailed joint should normally contain at least two nails.

Hardwoods in strength classes D30 to D70 will usually require pre-drilling. The diameter of pre-drilled holes should be not greater than 0.8 times the nail diameter.

Skew nailing slightly increases the resistance to withdrawal. Nails loaded laterally should not be skew-driven except at joints where no reversal of stress can occur in service and where the direction of the skew is such that the joint will tend to tighten under load. Opposed double skew nailing is preferable to parallel skew nailing.

### 6.4.2 Effective cross-section

When assessing the effective cross-section of multiple nail joints, all nails that lie within a distance of five nail diameters, measured parallel to the grain, from a given cross-section should be considered as occurring at that cross-section. Then the effective cross-section should be determined by deducting the net projected area of the nails from the gross area of the cross-section being considered.

No reduction of cross-section need be made for nails of less than 5 mm diameter, driven without pre-drilling.

### 6.4.3 Nail spacing

The end distances, edge distances and spacing of nails should be such as to avoid undue splitting and, unless shown by test to be satisfactory, should not be less than the values given in Table 60.

For all softwoods except Douglas fir, the spacings given in Table 60 for timber-to-timber joints should be multiplied by 0.8. For nails driven at right angles to the glued surface of pre-glued laminated members, the spacings should be further multiplied by 0.9. In no case, however, should the edge distance in the timber be less than 5*d*.

### 6.4.4 Timber-to-timber joints

#### 6.4.4.1 *Basic single shear lateral loads*

The basic single shear lateral loads for single round wire nails with a minimum tensile strength of 600 N/mm$^2$, driven at right angles to the side grain of timber in service classes 1 and 2, are given in Table 61.

For nails driven into pre-drilled holes in softwood strength classes C14 to C40 and TR26, the values given in Table 61 may be multiplied by 1.15.

For nails driven into the end grain of timber, the values given in Table 61 should be multiplied by the end grain modification factor, $K_{43}$, which has a value of 0.7.

For the basic loads in Table 61 to apply, the nails should fully penetrate the tabulated standard values in both the headside member and the member receiving the nail point.

For softwoods where the thicknesses of members or nail penetrations are less than the standard values given in Table 61, the basic load should be multiplied by the smaller of the two ratios:

a) actual to standard thickness of headside member; or

b) actual penetration to standard pointside thickness.

No load-carrying capacity should be assumed where the ratios described in a) or b) are less than 0.66 for softwoods and 1.0 for hardwoods. Where improved nails (see **6.4.4.4**) are used, the ratios may be reduced to 0.50 for softwoods and 0.75 for hardwoods.

No increase in basic load is permitted for thicknesses or penetrations greater than the standard values.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

#### 6.4.4.2 *Basic multiple shear lateral loads*

The basic multiple shear lateral load for each nail should be obtained by multiplying the value given in Table 61 by the number of shear planes, provided that the thickness of the inner member is not less than 0.85 times the standard thickness given in Table 61. Where the outer member thickness or nail penetrations in the outer softwood members are less than the standard value given in Table 61, or where the thickness of the inner softwood member is less than 0.85 of the standard thickness, the basic load should be reduced in accordance with the ratios given in **6.4.4.1**.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

**6.4.4.3** ***Basic withdrawal loads***

The basic withdrawal loads for single nails at right angles to the side of timber in service classes 1 and 2 are given in Table 62. These apply to each 1 mm depth of penetration, and for a particular nail should be multiplied by the actual pointside penetration achieved.

The penetration of the nail should be not less than 15 mm.

No withdrawal load should be carried by a nail driven into the end grain of timber.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

**Table 59 — Fastener slip moduli, $K_{ser}$, per fastener per shear plane for service classes 1 and 2**

| Fastener type | $K_{ser}$ | |
|---|---|---|
| | **Timber-to-timber or panel-to-timber** N/mm | **Steel-to-timber** [a] N/mm |
| Nails (no pre-drilling) | $\rho^{1.5}d^{0.8}/25$ | $\rho^{1.5}d^{0.8}/15$ |
| Nails (pre-drilled)<br>Screws<br>Bolts and dowels | $\rho^{1.5}d/20$ | $\rho^{1.5}d/12$ |

NOTE $\rho$ is the joint member characteristic density (see Table 8 and Table 9) in kilograms per cubic metre (kg/m³);

$d$ is the fastener diameter (in mm).

[a] For the values in this column to apply, the holes in the steel plate should be the minimum clearance diameter and the steel plate should have a thickness of 1.2 mm or 0.3 times the fastener diameter, whichever is the greater.

**Table 60 — Minimum nail spacings**

| Spacing | Timber-to-timber joints | | Steel plate-to-timber joints | Joints between timber and plywood or particleboard |
|---|---|---|---|---|
| | **Without pre-drilled holes** | **With pre-drilled holes** | **Without pre-drilled holes** | **Without pre-drilled holes** |
| End distance parallel to grain | $20d$ | $14d$ | $14d$ | $14d$ |
| Edge distance perpendicular to grain | $5d$ | $5d$ | $5d$ | — [a] |
| Distance between lines of nails, perpendicular to grain | $10d$ | $3d$ | $7d$ | $7d$ |
| Distance between adjacent nails in any one line, parallel to grain | $20d$ | $10d$ | $14d$ | $14d$ |

NOTE $d$ is the nail diameter.

[a] The loaded edge distance in the timber should be not less than $5d$. The loaded edge distance in the plywood should be not less than $3d$. The loaded edge distance in the particleboard should be not less than $6d$. In all other cases the edge distance should be not less than $3d$.

**Table 61 — Basic single shear lateral load for round wire nails in a timber-to-timber joint**

| Softwoods (not pre-drilled) | | | | | | Hardwoods (pre-drilled) | | |
|---|---|---|---|---|---|---|---|---|
| Nail diameter | Standard penetration [a] | Basic single shear lateral load N | | | | Minimum penetration [a] | Basic single shear lateral load N | |
| | | Strength class | | | | | Strength class | |
| | | C14 | C16/18/20 TR20/C22 | C24 | TR26/C27 C30/35/40 | | D35/40/45 | D50/60/70 |
| mm | mm | | | | | mm | | |
| 2.7 | 32 | 249 | 258 | 274 | 281 | 22 | 386 | 427 |
| 3 | 36 | 296 | 306 | 326 | 335 | 24 | 465 | 515 |
| 3.4 | 41 | 364 | 377 | 400 | 412 | 27 | 582 | 644 |
| 3.8 | 46 | 438 | 453 | 481 | 495 | 30 | 709 | 785 |
| 4.2 | 50 | 516 | 534 | 567 | 583 | 34 | 897 | 939 |
| 4.6 | 55 | 600 | 620 | 659 | 678 | 37 | 996 | 1 103 |
| 5 | 60 | 689 | 712 | 756 | 778 | 40 | 1 155 | 1 279 |
| 5.5 | 66 | 806 | 833 | 885 | 910 | 44 | 1 368 | 1 515 |
| 6 | 72 | 930 | 962 | 1 022 | 1 051 [b] | 48 | 1 595 | 1 767 |
| 7 | 84 | 1 200 | 1 240 | 1 318 | 1 355 [b] | 56 | 2 094 | 2 319 |
| 8 | 96 | 1 495 | 1 546 | 1 643 | 1 689 [b] | 64 | 2 649 | 2 933 |

[a] These values apply to both the headside and pointside penetration.
[b] Holes should be pre-drilled.

**Table 62 — Basic withdrawal loads per millimetre of pointside penetration for smooth round wire nails driven at right angles to the grain**

| Nail diameter | Basic withdrawal load N/mm | | | | | |
|---|---|---|---|---|---|---|
| | Strength class | | | | | |
| mm | C14 | C16/18/20/22/TR20 | C24 | TR26/C27 | D35/40/45 | D50/60/70 |
| 2.7 | 1.30 | 1.53 | 2.08 | 2.39 | 5.87 | 9.77 |
| 3 | 1.44 | 1.71 | 2.31 | 2.65 | 6.52 | 10.86 |
| 3.4 | 1.64 | 1.93 | 2.62 | 3.01 | 7.39 | 12.31 |
| 3.8 | 1.83 | 2.16 | 2.93 | 3.36 | 8.26 | 13.75 |
| 4.2 | 2.02 | 2.39 | 3.23 | 3.72 | 9.13 | 15.20 |
| 4.6 | 2.21 | 2.62 | 3.54 | 4.07 | 10.00 | 16.65 |
| 5 | 2.41 | 2.84 | 3.85 | 4.42 | 10.86 | 18.10 |
| 5.5 | 2.65 | 3.13 | 4.24 | 4.87 | 11.95 | 19.91 |
| 6 | 2.89 | 3.41 | 4.62 | 5.31 | 13.04 | 21.72 |
| 7 | 3.37 | 3.98 | 5.39 | 6.19 | 15.21 | 25.33 |
| 8 | 3.85 | 4.55 | 6.16 | 7.08 | 17.38 | 28.95 |

**6.4.4.4** ***Improved nails***

For square grooved and square twisted shank nails of steel with a yield stress of not less than 375 N/mm$^2$, the basic lateral loads given in Table 61 should be multiplied by the improved nail lateral modification factor, $K_{44}$, which has the value 1.20. A nominal diameter equal to the side length of the nail should be assumed for these improved nails.

For the threaded part of annular ringed shank and helical threaded shank nails, the basic withdrawal loads given in Table 62 should be multiplied by the improved nail withdrawal modification factor, $K_{45}$, which has the value 1.5.

No withdrawal load should be carried by an improved nail when driven into the end grain of timber.

**6.4.5 Steel plate-to-timber joints**

**6.4.5.1** ***Steel plate***

Steel plates should have a minimum thickness of 1.2 mm or 0.3 times the nail diameter for the modification factors described in **6.4.5.2** to apply.

**6.4.5.2** ***Basic loads***

Where a pre-drilled steel component or plate of adequate strength is nailed to a timber member, the basic lateral load given in Table 61 should be multiplied by the steel-to-timber modification factor, $K_{46}$, which has the value 1.25. The diameter of the hole in the steel plate should be not greater than the diameter of the nail.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

**6.4.6 Plywood-to-timber joints**

**6.4.6.1** ***Plywood***

The plywood should be selected from those given in section **4**.

**6.4.6.2** ***Basic loads***

The basic single shear lateral loads for single nails in a plywood-to-timber joint, where the nails are driven through the plywood at right angles into the side grain of timber in service classes 1 and 2, are given in Table 63.

For the basic loads in Table 63 to apply, the nails should be fully embedded, and should have an overall length not less than those tabulated. For nominal plywood thicknesses that are intermediate between the tabulated values, loads may be obtained by linear interpolation.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

**6.4.7** *Text deleted.*

**6.4.8 Particleboard-to-timber joints**

**6.4.8.1** ***Wood particleboard***

The wood particleboard should be in accordance with section **5**.

**6.4.8.2** ***Basic loads***

The basic single shear lateral loads for single nails in a wood particleboard-to-timber joint, where the nails are driven through the particleboard at right angles into the side grain of timber in service classes 1 and 2, are given in Table 64.

For the basic loads in Table 64 to apply, the nails should be fully embedded and be of an overall length not less than:

a) 2.5 times the nominal particleboard thickness for particleboards in the range 6 mm to 19 mm thick;

b) 2.0 times the nominal particleboard thickness for particleboards in the range 20 mm to 40 mm thick.

The basic loads given in this clause for each nail should be modified in accordance with **6.4.9** to determine the permissible load for a joint.

**Table 63 — Basic single shear lateral load for round wire nails in a plywood-to-timber joint**

| Plywood nominal thickness | Nail diameter | Nail length | Basic single shear lateral load N | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Softwoods (not pre-drilled) | | | | | | Hardwoods (pre-drilled) | | | | | |
| | | | Strength class | | | | | | Strength class | | | | | |
| | | | C14 | | C16/18/20/TR20/C22 | | C24 | | TR26/C27/30/35/40 | | D35/40/50 | | D50/60/70 | |
| | | | Plywood group [a] | | | | | | Plywood group [a] | | | | | |
| mm | mm | mm | I | II | I | II | I | II | I | II | I | II | I | II |
| 6 | 2.7 | 40 | 213 | 122 | 218 | 227 | 226 | 236 | 230 | 241 | 275 | 290 | 275 | 305 |
| | 3.0 | 50 | 252 | 261 | 257 | 267 | 268 | 279 | 273 | 284 | 296 | 346 | 296 | 360 |
| | 3.4 | 50 | 308 | 318 | 315 | 326 | 323 | 340 | 323 | 346 | 323 | 393 | 323 | 393 |
| | 3.8 | 75 | 349 | 381 | 349 | 390 | 349 | 407 | 349 | 415 | 349 | 425 | 349 | 425 |
| | 4.2 | 75 | 374 | 448 | 374 | 455 | 374 | 455 | 374 | 455 | 374 | 455 | 374 | 455 |
| 9 | 2.7 | 40 | 220 | 231 | 229 | 244 | 237 | 257 | 241 | 261 | 282 | 309 | 295 | 324 |
| | 3.0 | 50 | 261 | 280 | 266 | 286 | 276 | 297 | 281 | 302 | 333 | 362 | 347 | 379 |
| | 3.4 | 50 | 315 | 335 | 322 | 342 | 334 | 356 | 339 | 362 | 407 | 440 | 425 | 461 |
| | 3.8 | 75 | 374 | 394 | 382 | 403 | 397 | 420 | 403 | 428 | 490 | 525 | 502 | 551 |
| | 4.2 | 75 | 437 | 459 | 447 | 470 | 465 | 489 | 473 | 498 | 538 | 619 | 538 | 650 |
| 12 | 2.7 | 45 | 244 | 258 | 250 | 271 | 259 | 284 | 263 | 289 | 305 | 339 | 317 | 353 |
| | 3.0 | 50 | 281 | 306 | 287 | 312 | 297 | 324 | 302 | 329 | 353 | 390 | 368 | 407 |
| | 3.4 | 50 | 321 | 337 | 339 | 355 | 353 | 381 | 358 | 387 | 424 | 464 | 442 | 485 |
| | 3.8 | 75 | 391 | 418 | 399 | 427 | 413 | 443 | 420 | 451 | 503 | 546 | 524 | 571 |
| | 4.2 | 75 | 452 | 481 | 462 | 491 | 479 | 510 | 487 | 519 | 589 | 635 | 614 | 665 |
| 15 | 2.7 | 50 | 270 | 287 | 277 | 300 | 286 | 316 | 291 | 321 | 335 | 374 | 347 | 389 |
| | 3.0 | 65 | 308 | 337 | 314 | 343 | 324 | 356 | 329 | 361 | 383 | 424 | 397 | 442 |
| | 3.4 | 65 | 360 | 390 | 367 | 398 | 379 | 412 | 385 | 419 | 452 | 497 | 469 | 518 |
| | 3.8 | 75 | 415 | 448 | 424 | 457 | 439 | 474 | 445 | 481 | 528 | 577 | 549 | 602 |
| | 4.2 | 75 | 476 | 509 | 485 | 520 | 503 | 540 | 511 | 549 | 611 | 664 | 635 | 692 |

[a] Plywood group I comprises American construction and industrial plywood, Canadian Douglas fir plywood, Canadian softwood plywood, Finnish conifer plywood and Swedish softwood plywood. Plywood group II comprises Finnish birch-faced plywood and Finnish birch plywood.

**Table 63 — Basic single shear lateral load for round wire nails in a plywood-to-timber joint** (*continued*)

| Plywood nominal thickness | Nail diameter | Nail length | Basic single shear lateral load N | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Softwoods (not pre-drilled) | | | | | | Hardwoods (pre-drilled) | | | | | |
| | | | Strength class | | | | | | Strength class | | | | | |
| | | | C14 | | C16/18/20/TR20/C22 | | C24 | | TR26/C27/30/35/40 | | D35/40/50 | | D50/60/70 | |
| | | | Plywood group [a] | | | | | | Plywood group [a] | | | | | |
| mm | mm | mm | I | II | I | II | I | II | I | II | I | II | I | II |
| 18 | 2.7 | 50 | 274 | 295 | 285 | 306 | 307 | 324 | 318 | 330 | 370 | 401 | 383 | 422 |
| | 3.0 | 65 | 339 | 360 | 345 | 369 | 356 | 385 | 361 | 393 | 418 | 462 | 433 | 480 |
| | 3.4 | 65 | 390 | 424 | 398 | 432 | 411 | 447 | 417 | 454 | 487 | 535 | 505 | 556 |
| | 3.8 | 75 | 446 | 481 | 455 | 491 | 470 | 508 | 477 | 516 | 562 | 614 | 583 | 639 |
| | 4.2 | 75 | 506 | 542 | 516 | 553 | 534 | 574 | 542 | 583 | 643 | 699 | 668 | 727 |
| 21 | 2.7 | 50 | 279 | 284 | 292 | 297 | 315 | 323 | 321 | 329 | 384 | 400 | 403 | 421 |
| | 3.0 | 65 | 352 | 360 | 360 | 368 | 375 | 385 | 382 | 392 | 457 | 479 | 473 | 505 |
| | 3.4 | 65 | 413 | 438 | 432 | 453 | 447 | 473 | 453 | 482 | 527 | 580 | 546 | 603 |
| | 3.8 | 75 | 481 | 521 | 490 | 531 | 506 | 549 | 514 | 558 | 602 | 660 | 623 | 685 |
| | 4.2 | 75 | 541 | 578 | 551 | 594 | 570 | 615 | 578 | 624 | 683 | 745 | 707 | 773 |
| 29 | 2.7 | 50 | 238 | 240 | 247 | 249 | 266 | 268 | 275 | 278 | 384 | 392 | 403 | 412 |
| | 3.0 | 65 | 352 | 356 | 360 | 364 | 375 | 380 | 382 | 387 | 461 | 470 | 483 | 494 |
| | 3.4 | 65 | 408 | 411 | 427 | 431 | 461 | 467 | 469 | 476 | 571 | 583 | 598 | 612 |
| | 3.8 | 75 | 519 | 525 | 531 | 538 | 554 | 561 | 564 | 572 | 691 | 706 | 723 | 740 |
| | 4.2 | 75 | 570 | 592 | 591 | 613 | 633 | 656 | 654 | 674 | 810 | 838 | 837 | 878 |

[a] Plywood group I comprises American construction and industrial plywood, Canadian Douglas fir plywood, Canadian softwood plywood, Finnish conifer plywood and Swedish softwood plywood. Plywood group II comprises Finnish birch-faced plywood and Finnish birch plywood.

**Table 64 — Basic single shear lateral loads for round wire nails in P5 grade or better particleboard-to-timber joints**

| Nominal particle board thickness mm | Nail diameter mm | Basic single shear lateral load N | | | | | |
|---|---|---|---|---|---|---|---|
| | | Strength class | | | | | |
| | | C14 | C16/18/20/ TR20/C22 | C24 | C27/30/35/40 | D30/35/40 | D50/60/70 |
| 6 | 2.7 [a] | 60 | 63 | 71 | 74 | 102 | 120 |
| | 3.0 [a] | 64 | 68 | 76 | 79 | 109 | 129 |
| | 3.4 | 68 | 72 | 80 | 84 | 116 | 137 |
| | 3.8 | 88 | 94 | 105 | 111 | 155 | 186 |
| | 4.2 | 101 | 108 | 121 | 128 | 179 | 216 |
| 9 | 2.7 [a] | 62 | 65 | 73 | 77 | 105 | 124 |
| | 3.0 [a] | 68 | 72 | 80 | 84 | 115 | 134 |
| | 3.4 | 73 | 78 | 87 | 91 | 125 | 147 |
| | 3.8 | 94 | 101 | 112 | 118 | 164 | 196 |
| | 4.2 | 107 | 115 | 128 | 135 | 189 | 227 |
| 11/12 | 2.7 [a] | 63 | 67 | 75 | 78 | 107 | 126 |
| | 3.0 [a] | 70 | 74 | 83 | 87 | 119 | 140 |
| | 3.4 | 77 | 81 | 91 | 95 | 131 | 154 |
| | 3.8 | 99 | 104 | 117 | 123 | 170 | 203 |
| | 4.2 | 112 | 119 | 133 | 140 | 195 | 234 |
| 15/16 | 2.7 [a] | 66 | 70 | 78 | 82 | 111 | 131 |
| | 3.0 [a] | 75 | 80 | 89 | 93 | 127 | 150 |
| | 3.4 | 84 | 89 | 99 | 104 | 143 | 169 |
| | 3.8 | 106 | 113 | 126 | 132 | 183 | 218 |
| | 4.2 | 120 | 128 | 143 | 150 | 208 | 248 |
| 18/19 | 2.7 [a] | 68 | 72 | 80 | 84 | 114 | 134 |
| | 3.0 [a] | 79 | 84 | 93 | 98 | 133 | 157 |
| | 3.4 | 89 | 95 | 106 | 111 | 152 | 179 |
| | 3.8 | 112 | 119 | 133 | 140 | 192 | 228 |
| | 4.2 | 126 | 134 | 150 | 158 | 217 | 259 |
| 22 | 2.7 [a] | 70 | 75 | 83 | 87 | 118 | 139 |
| | 3.0 [a] | 83 | 89 | 99 | 104 | 141 | 166 |
| | 3.4 | 96 | 102 | 114 | 120 | 164 | 193 |
| | 3.8 | 119 | 127 | 142 | 150 | 205 | 242 |
| | 4.2 | 134 | 143 | 159 | 168 | 230 | 273 |
| 30 | 2.7 [a] | 76 | 80 | 90 | 94 | 127 | 148 |
| | 3.0 [a] | 93 | 99 | 111 | 116 | 157 | 185 |
| | 3.4 | 110 | 117 | 131 | 138 | 187 | 221 |
| | 3.8 | 135 | 144 | 161 | 169 | 230 | 271 |
| | 4.2 | 151 | 160 | 179 | 188 | 256 | 302 |
| 38/40 | 2.7 [a] | 81 | 86 | 96 | 100 | 135 | 157 |
| | 3.0 [a] | 103 | 110 | 122 | 128 | 173 | 203 |
| | 3.4 | 125 | 133 | 148 | 155 | 211 | 249 |
| | 3.8 | 151 | 160 | 179 | 187 | 255 | 300 |
| | 4.2 | 167 | 177 | 198 | 207 | 282 | 331 |

[a] Standard length nails are not available for the complete particleboard thickness range.

### 6.4.9 Permissible load for a joint

The permissible load for a nailed joint should be determined as the sum of the permissible loads for each nail in the joint, where each permissible nail load, $F_{adm}$, should be calculated from the equation:

$$F_{adm} = F \times K_{48} \times K_{49} \times K_{50}$$

where the basic load for a nail, $F$, is taken from **6.4.4**, **6.4.5.2**, **6.4.6.2** or **6.4.8.2** as appropriate, and where:

$K_{48}$ is the modification factor for duration of loading;

$K_{49}$ is the modification factor for moisture content;

$K_{50}$ is the modification factor for the number of nails in each line.

For duration of loading:

$K_{48}$ = 1.00 for long-term loads;

$K_{48}$ = 1.40 for particleboard-to-timber joints: medium-term loads;

$K_{48}$ = 1.12 for other than particleboard-to-timber joints: medium-term loads;

$K_{48}$ = 2.10 for particleboard-to-timber joints: short- and very short-term loads;

$K_{48}$ = 1.25 for other than particleboard-to-timber joints: short- and very short-term loads.

For moisture content:

$K_{49}$ = 1.00 for lateral loads in joints in service classes 1 and 2;

$K_{49}$ = 0.70 for lateral loads in timber-to-timber joints in service class 3;

$K_{49}$ = 1.00 for lateral loads using annular ringed shank nails and helical threaded shank nails in all service class conditions;

$K_{49}$ = 1.00 for withdrawal loads in all constant service class conditions;

$K_{49}$ = 0.25 for withdrawal loads where cyclic changes in moisture content can occur after nailing.

NOTE The use of particleboard in service class 3 is not recommended.

For the number of nails in each line:

where a number of nails of the same diameter, acting in single or multiple shear, are symmetrically arranged in one or more lines parallel to the line of action of the load in a primarily axially loaded member in a structural framework (see **1.6.11**), then:

$K_{50} = 1.0$ for $n < 10$;

$K_{50} = 0.9$ for $n \geq 10$;

where $n$ is the number of nails in each line.

In all other loading cases where more than one nail is used in a joint:

$K_{50} = 1.0$

## 6.5 Screwed joints

### 6.5.1 General

The recommendations contained in **6.5** are applicable to steel screws which conform to BS 1210 and have a minimum tensile strength of 550 N/mm².

Screws should be turned, not hammered, into pre-drilled holes. The hole for the shank should have a diameter equal to the shank diameter and be no deeper than the length of the shank. The pilot hole for the threaded portion of the screw should have a diameter of about half the shank diameter. The tops of countersunk screws should be no more than 1 mm below the surface of the timber. A non-corrosive lubricant may be used to facilitate insertion.



### 6.5.2 Effective cross-section

When assessing the effective cross-section of multiple screw joints, all screws that lie within a distance of five screw diameters measured parallel to the grain from a given cross-section should be considered as occurring at that cross-section. The effective cross-section should then be determined by deducting the net projected area of the pre-drilled holes from the gross area of the cross-section being considered.

No reduction of cross-section need be made for screws of less than 5 mm diameter.

### 6.5.3 Screw spacing

The end distances, edge distances and spacings of screws should be such as to avoid undue splitting and should be not less than the values given in Table 65.

**Table 65 — Minimum screw spacings**

| Spacing | Distance with pre-drilled holes |
|---|---|
| End distance parallel to grain | 10$d$ |
| Edge distance perpendicular to grain | 5$d$ |
| Distance between lines of screws, perpendicular to the grain | 3$d$ |
| Distance between adjacent screws in any one line, parallel to grain | 10$d$ |
| NOTE $d$ is the shank diameter of the screw. | |

### 6.5.4 Timber-to-timber joints

#### 6.5.4.1 *Basic single shear lateral loads*

The basic single shear lateral loads for single screws inserted at right angles to the side grain of timber in service classes 1 and 2 are given in Table 66.

For screws inserted into the end grain of timber the values given in Table 66 should be multiplied by the end grain modification factor, $K_{43}$, which has a value of 0.7.

For the basic loads in Table 66 to apply, the headside member thickness should be not less than the value given in Table 66, and the penetration of the screw in the pointside member should be at least that given in Table 66.

Where the thickness of the headside member is less than the value given in Table 66, the tabulated basic load should be multiplied by the ratio of the actual to the standard headside thickness, provided that the pointside screw penetration is at least twice the actual headside thickness. The minimum headside member thickness should be not less than twice the shank diameter.

No increase in basic load is permitted for thicknesses or penetrations greater than the standard values.

The basic loads given in this clause for each screw should be modified in accordance with **6.5.7** to determine the permissible load for a joint.

#### 6.5.4.2 *Basic withdrawal loads*

The basic withdrawal loads for single screws inserted at right angles to the side grain of timber in service classes 1 and 2 are given in Table 67. These apply to each 1 mm depth of penetration and, for a particular screw, should be multiplied by the actual pointside penetration achieved by the threaded part of the screw.

The penetration of the screw point should be not less than 15 mm.

No withdrawal load should be carried by a screw driven into the end grain of timber.

The basic loads given in this clause for each screw should be modified in accordance with **6.5.7** to determine the permissible load for a joint.

### 6.5.5 Steel plate-to-timber joints

#### 6.5.5.1 *Steel plate*

Steel plates should have a minimum thickness of 1.2 mm or 0.25 times the shank diameter, whichever is the greater, for the modification factors in **6.5.5.2** to apply.

The diameter of the hole in the steel plate should be not greater than the shank diameter of the screw.

**6.5.5.2** ***Basic loads***

Where a pre-drilled steel component or plate of adequate strength is screwed to a timber member, the basic lateral load given in Table 66 should be multiplied by the steel-to-timber modification factor, $K_{46}$, which has the value 1.25.

The basic loads given in this clause for each screw should be modified in accordance with **6.5.7** to determine the permissible load for a joint.

### 6.5.6 Plywood-to-timber joints

**6.5.6.1** ***Plywood***

The plywood should be selected from those given in section **4**.

The diameter of the pre-drilled hole in the plywood should be not greater than the shank diameter of the screw.

**6.5.6.2** ***Basic loads***

The basic single shear lateral loads for single screws in a plywood-to-timber joint, where screws of the specified minimum length are inserted through the plywood at right angles into the side grain of timber in service classes 1 and 2, are given in Table 68.

The basic loads given in this clause for each screw should be modified in accordance with **6.5.7** to determine the permissible load for a joint.

**Table 66 — Basic single shear lateral loads for screws inserted into pre-drilled holes in a timber-to-timber joint**

| Screw shank diameter | Standard penetration mm | | Basic single shear lateral load N | | | | |
|---|---|---|---|---|---|---|---|
| | | | Strength class | | | | |
| | Headside | Pointside | C14 | C16/18/20 TR20/C22 | C24 | TR26/C27 C30/40/50 | D35/40/45 50/60/70 |
| mm | mm | mm | | | | | |
| 3 | 11 | 21 | 192 | 205 | 205 | 232 | 304 |
| 3.5 | 12 | 25 | 260 | 278 | 310 | 321 | 405 |
| 4 | 14 | 28 | 338 | 361 | 395 | 409 | 518 |
| 4.5 | 16 | 32 | 425 | 454 | 490 | 507 | 643 |
| 5 | 18 | 35 | 511 | 550 | 593 | 615 | 781 |
| 5.5 | 19 | 39 | 628 | 654 | 705 | 731 | 931 |
| 6 | 21 | 42 | 734 | 765 | 826 | 856 | 1 092 |
| 7 | 25 | 49 | 970 | 1 011 | 1 093 | 1 133 | 1 449 |
| 8 | 28 | 56 | 1 233 | 1 286 | 1 391 | 1 443 | 1 849 |
| 10 | 35 | 70 | 1 504 | 1 608 | 1 741 | 1 803 | 2 285 |

**Table 67 — Basic withdrawal loads per millimetre of pointside penetration for screws turned at right angles to the grain**

| **Screw diameter** mm | **Basic withdrawal load** N/mm | | | | |
|---|---|---|---|---|---|
| | **Strength class** | | | | |
| | **C14** | **C16/18/20 TR20/C22** | **C24** | **TR26/C27 C30/35/40** | **D35/40/45 50/60/70** |
| 3 | 7.57 | 8.65 | 11.02 | 12.32 | 25.28 |
| 3.5 | 8.83 | 10.09 | 12.86 | 14.37 | 29.49 |
| 4 | 10.09 | 11.53 | 14.70 | 16.43 | 33.11 |
| 4.5 | 11.35 | 12.97 | 16.54 | 18.48 | 31.92 |
| 5 | 12.61 | 14.41 | 18.37 | 20.53 | 42.13 |
| 5.5 | 13.88 | 15.86 | 20.21 | 22.59 | 46.35 |
| 6 | 15.14 | 17.30 | 22.05 | 24.64 | 50.56 |
| 7 | 11.66 | 20.18 | 25.72 | 28.75 | 58.99 |
| 8 | 20.18 | 23.06 | 29.40 | 32.86 | 67.42 |
| 10 | 25.23 | 28.83 | 36.75 | 41.07 | 84.27 |

**Table 68 — Basic single shear lateral load for screws inserted into pre-drilled holes in a plywood-to-timber joint**

| Plywood thickness, $t$ | Screw diameter, $d$ | Minimum pointside penetration [a], $4d + t$ | Basic single shear lateral load N | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strength class | | | | | | | | | | | |
| | | | C14 | | C16/18/20/TR20/C22 | | C24 | | TR26/C27/30/35/40 | | D35/40/45 | | D50/60/70 | |
| | | | Plywood group [b] | | | | | | | | | | | |
| mm | mm | mm | I | II | I | II | I | II | I | II | I | II | I | II |
| 6 | 3 | 18 | 130 | 139 | 136 | 145 | 148 | 157 | 154 | 163 | 201 | 211 | 234 | 246 |
| | 3.5 | 20 | 167 | 177 | 176 | 185 | 193 | 202 | 201 | 211 | 266 | 277 | 313 | 326 |
| | 4 | 22 | 211 | 220 | 222 | 232 | 244 | 255 | 256 | 266 | 342 | 355 | 362 | 419 |
| | 4.5 | 24 | 260 | 271 | 275 | 285 | 304 | 315 | 318 | 329 | 393 | 443 | 393 | 478 |
| | 5 | 26 | 316 | 327 | 334 | 345 | 370 | 382 | 387 | 400 | 423 | 515 | 423 | 515 |
| | 5.5 | 28 | 377 | 389 | 399 | 411 | 443 | 456 | 452 | 478 | 452 | 550 | 452 | 550 |
| | 6 | 30 | 445 | 457 | 471 | 484 | 481 | 537 | 481 | 563 | 481 | 585 | 481 | 585 |
| | 7 | 34 | 535 | 610 | 535 | 647 | 535 | 651 | 535 | 651 | 535 | 651 | 535 | 651 |
| | 8 | 38 | 588 | 715 | 588 | 715 | 588 | 715 | 588 | 715 | 588 | 715 | 588 | 715 |
| 9 | 3 | 21 | 152 | 171 | 157 | 176 | 168 | 187 | 173 | 193 | 214 | 235 | 244 | 266 |
| | 3.5 | 23 | 187 | 207 | 195 | 215 | 210 | 230 | 217 | 238 | 276 | 298 | 318 | 342 |
| | 4 | 25 | 228 | 249 | 238 | 259 | 259 | 280 | 269 | 291 | 347 | 371 | 404 | 430 |
| | 4.5 | 27 | 275 | 297 | 288 | 310 | 315 | 337 | 328 | 350 | 429 | 455 | 502 | 530 |
| | 5 | 29 | 328 | 350 | 344 | 367 | 377 | 401 | 394 | 418 | 521 | 548 | 608 | 643 |
| | 5.5 | 31 | 386 | 409 | 407 | 430 | 447 | 472 | 467 | 492 | 622 | 652 | 650 | 768 |
| | 6 | 33 | 450 | 474 | 475 | 500 | 524 | 549 | 548 | 574 | 691 | 767 | 691 | 877 |
| | 7 | 37 | 596 | 622 | 630 | 656 | 696 | 725 | 730 | 759 | 770 | 977 | 770 | 977 |
| | 8 | 41 | 763 | 791 | 807 | 837 | 845 | 928 | 845 | 973 | 845 | 1 073 | 845 | 1 073 |

[a] For pointside penetration greater than the minimum given in this table use Annex G.
[b] Plywood group I comprises American construction and industrial plywood, Canadian Douglas fir plywood, Canadian softwood plywood, Finnish conifer plywood and Swedish softwood plywood. Plywood group II comprises Finnish birch-faced plywood and Finnish birch plywood.

**Table 68 — Basic single shear lateral load for screws inserted into pre-drilled holes in a plywood-to-timber joint** (*continued*)

| Plywood thickness, $t$ | Screw diameter, $d$ | Minimum pointside penetration [a], $4d + t$ | Basic single shear lateral load N | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strength class | | | | | | | | | | | |
| | | | C14 | | C16/18/20/TR20/C22 | | C24 | | TR26/C27/30/35/40 | | D35/40/45 | | D50/60/70 | |
| | | | Plywood group [b] | | | | | | | | | | | |
| mm | mm | mm | I | II | I | II | I | II | I | II | I | II | I | II |
| 12 | 3 | 24 | 182 | 208 | 187 | 213 | 197 | 224 | 202 | 229 | 240 | 268 | 267 | 296 |
| | 3.5 | 26 | 217 | 245 | 224 | 252 | 238 | 266 | 245 | 273 | 298 | 328 | 337 | 368 |
| | 4 | 28 | 257 | 286 | 267 | 296 | 285 | 315 | 295 | 324 | 367 | 398 | 419 | 452 |
| | 4.5 | 30 | 303 | 332 | 315 | 345 | 339 | 370 | 351 | 382 | 445 | 478 | 513 | 548 |
| | 5 | 32 | 353 | 384 | 369 | 400 | 399 | 431 | 415 | 447 | 533 | 568 | 618 | 656 |
| | 5.5 | 34 | 410 | 441 | 429 | 460 | 466 | 499 | 485 | 518 | 631 | 668 | 736 | 776 |
| | 6 | 36 | 471 | 504 | 494 | 527 | 540 | 574 | 563 | 597 | 738 | 777 | 865 | 908 |
| | 7 | 40 | 612 | 646 | 644 | 679 | 707 | 743 | 738 | 776 | 982 | 1 026 | 1 026 | 1 207 |
| | 8 | 44 | 773 | 810 | 816 | 853 | 900 | 939 | 941 | 982 | 1 127 | 1 313 | 1 127 | 1 401 |
| 15 | 3 | 27 | 218 | 245 | 222 | 253 | 232 | 264 | 236 | 269 | 271 | 305 | 296 | 331 |
| | 3.5 | 29 | 253 | 286 | 260 | 293 | 273 | 307 | 279 | 314 | 329 | 365 | 365 | 402 |
| | 4 | 31 | 293 | 328 | 302 | 337 | 320 | 355 | 328 | 364 | 395 | 433 | 444 | 483 |
| | 4.5 | 33 | 338 | 374 | 349 | 386 | 372 | 409 | 383 | 421 | 471 | 511 | 534 | 575 |
| | 5 | 35 | 388 | 425 | 402 | 440 | 431 | 469 | 445 | 484 | 556 | 597 | 636 | 679 |
| | 5.5 | 37 | 442 | 481 | 460 | 499 | 496 | 535 | 513 | 553 | 650 | 694 | 749 | 795 |
| | 6 | 39 | 502 | 542 | 524 | 564 | 567 | 608 | 588 | 630 | 754 | 799 | 874 | 922 |
| | 7 | 43 | 638 | 680 | 669 | 711 | 729 | 772 | 759 | 803 | 990 | 1 040 | 1 157 | 1 211 |
| | 8 | 47 | 796 | 839 | 836 | 880 | 916 | 962 | 955 | 1 002 | 1 263 | 1 318 | 1 408 | 1 546 |
| 18 | 3 | 30 | 238 | 245 | 246 | 252 | 260 | 267 | 266 | 274 | 308 | 328 | 331 | 366 |
| | 3.5 | 32 | 293 | 322 | 300 | 332 | 312 | 350 | 319 | 356 | 365 | 405 | 398 | 439 |
| | 4 | 34 | 334 | 373 | 343 | 382 | 359 | 399 | 368 | 408 | 431 | 472 | 476 | 519 |
| | 4.5 | 36 | 379 | 420 | 390 | 431 | 412 | 453 | 422 | 464 | 504 | 548 | 563 | 609 |
| | 5 | 38 | 428 | 470 | 442 | 484 | 469 | 512 | 483 | 526 | 587 | 633 | 662 | 710 |
| | 5.5 | 40 | 482 | 526 | 499 | 543 | 533 | 577 | 550 | 594 | 679 | 726 | 772 | 822 |
| | 6 | 42 | 541 | 586 | 562 | 607 | 603 | 648 | 623 | 669 | 780 | 829 | 893 | 945 |
| | 7 | 46 | 674 | 721 | 703 | 750 | 760 | 809 | 789 | 837 | 1 009 | 1 062 | 1 168 | 1 225 |
| | 8 | 50 | 828 | 876 | 866 | 915 | 943 | 993 | 980 | 1 032 | 1 274 | 1 332 | 1 486 | 1 550 |

[a] For pointside penetration greater than the minimum given in this table use Annex G.

[b] Plywood group I comprises American construction and industrial plywood, Canadian Douglas fir plywood, Canadian softwood plywood, Finnish conifer plywood and Swedish softwood plywood. Plywood group II comprises Finnish birch-faced plywood and Finnish birch plywood.

**Table 68 — Basic single shear lateral load for screws inserted into pre-drilled holes in a plywood-to-timber joint** (*continued*)

| Plywood thickness, $t$ | Screw diameter, $d$ | Minimum pointside penetration [a], $4d + t$ | Basic single shear lateral load N | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strength class | | | | | | | | | | | |
| | | | C14 | | C16/18/20/TR20/C22 | | C24 | | TR26/C27/30/35/40 | | D35/40/45 | | D50/60/70 | |
| | | | Plywood group [b] | | | | | | | | | | | |
| mm | mm | mm | I | II | I | II | I | II | I | II | I | II | I | II |
| 21 | 3 | 33 | 238 | 244 | 246 | 252 | 260 | 266 | 266 | 274 | 317 | 327 | 353 | 365 |
| | 3.5 | 35 | 314 | 321 | 323 | 332 | 342 | 351 | 351 | 361 | 406 | 433 | 437 | 483 |
| | 4 | 37 | 379 | 408 | 387 | 421 | 403 | 446 | 411 | 457 | 471 | 519 | 513 | 563 |
| | 4.5 | 39 | 425 | 471 | 435 | 482 | 456 | 504 | 466 | 514 | 544 | 595 | 600 | 652 |
| | 5 | 41 | 475 | 523 | 488 | 537 | 514 | 563 | 526 | 577 | 625 | 678 | 696 | 751 |
| | 5.5 | 43 | 528 | 579 | 545 | 595 | 577 | 628 | 592 | 644 | 715 | 770 | 803 | 860 |
| | 6 | 45 | 587 | 638 | 606 | 659 | 645 | 698 | 664 | 718 | 813 | 870 | 921 | 980 |
| | 7 | 49 | 718 | 772 | 745 | 800 | 800 | 856 | 827 | 883 | 1 037 | 1 098 | 1 189 | 1 253 |
| | 8 | 53 | 868 | 925 | 905 | 962 | 978 | 1 037 | 1 014 | 1 074 | 1 296 | 1 361 | 1 499 | 1 569 |
| 29 | 3 | 41 | 238 | 241 | 246 | 249 | 260 | 263 | 266 | 270 | 317 | 323 | 353 | 359 |
| | 3.5 | 43 | 314 | 318 | 323 | 328 | 342 | 347 | 351 | 356 | 419 | 426 | 466 | 475 |
| | 4 | 45 | 398 | 403 | 410 | 416 | 434 | 440 | 446 | 452 | 534 | 543 | 594 | 605 |
| | 4.5 | 47 | 491 | 497 | 506 | 513 | 536 | 544 | 551 | 559 | 660 | 672 | 719 | 750 |
| | 5 | 49 | 592 | 600 | 611 | 619 | 647 | 656 | 662 | 675 | 751 | 790 | 813 | 854 |
| | 5.5 | 51 | 671 | 709 | 686 | 724 | 715 | 754 | 729 | 769 | 838 | 880 | 916 | 959 |
| | 6 | 53 | 730 | 770 | 748 | 788 | 784 | 824 | 801 | 842 | 934 | 976 | 1 029 | 1 073 |
| | 7 | 57 | 861 | 903 | 886 | 928 | 935 | 978 | 959 | 1 003 | 1 147 | 1 193 | 1 283 | 1 330 |
| | 8 | 61 | 1 008 | 1 051 | 1 041 | 1 085 | 1 107 | 1 152 | 1 140 | 1 185 | 1 394 | 1 442 | 1 577 | 1 627 |

[a] Plywood group I comprises American construction and industrial plywood, Canadian Douglas fir plywood, Canadian softwood plywood, Finnish conifer plywood and Swedish softwood plywood. Plywood group II comprises Finnish birch-faced plywood and Finnish birch plywood.
[b] For pointside penetration greater than the minimum given in this table use Annex G.

### 6.5.7 Permissible load for a joint

The permissible load for a screwed joint should be determined as the sum of the permissible loads for each screw in the joint where each permissible screw load, $F_{adm}$, should be calculated from the equation:

$$F_{adm} = F \times K_{52} \times K_{53} \times K_{54}$$

where the basic load for a screw, $F$, is taken from **6.5.4**, **6.5.5.2** or **6.5.6.2** as appropriate, and where:

$K_{52}$ is the modification factor for duration of loading;

$K_{53}$ is the modification factor for moisture content;

$K_{54}$ is the modification factor for the number of screws in each line.

For duration of loading:

$K_{52}$ = 1.00 for long-term loads;

$K_{52}$ = 1.12 for medium-term loads;

$K_{52}$ = 1.25 for short- and very short-term loads.

For moisture content:

$K_{53}$ = 1.0 for a joint in service classes 1 and 2;

$K_{53}$ = 0.7 for a joint in service class 3.

For the number of screws in each line:

where a number of screws of the same diameter, acting in single or multiple shear, are symmetrically arranged in one or more lines parallel to the line of action of the load in a primarily axially loaded member in a structural framework (see **1.6.11**) then:

$K_{54}$ = 1.0 for $n < 10$;

$K_{54}$ = 0.9 for $n \geq 10$;

where $n$ is the number of screws in each line.

In all other loading cases where more than one screw is used in a joint:

$K_{54} = 1.0$

## 6.6 Bolted and dowelled joints

### 6.6.1 General

The recommendations contained in **6.6** are applicable to joints utilizing black bolts which conform to BS EN 20898-1 and have a minimum tensile strength of 400 N/mm² and washers which conform to BS 4320. Advantage can be taken of the end fixity provided by the head, nut and washers to improve the strength of a two-member bolted joint by including the factor $K_{2b}$ in equation G.3 (see Annex G). Values for bolts calculated on this basis are given in Table 69, Table 70, Table 71, Table 72, Table 73 and Table 74. For bolts or dowels made of higher strength steel the equations given in Annex G may give higher load carrying capacities than given in Table 69, Table 70, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80.

Bolt holes should be drilled to diameters as close as practicable to the nominal bolt diameter, but in no case should they be more than 2 mm larger than the bolt diameter.

Washers with a nominal diameter and thickness of at least 3.0 times and 0.25 times the bolt diameter, respectively, should be fitted under the head of each bolt and under each nut unless an equivalent bearing area is provided, for example, by a steel plate. If square washers are used, their side length and thickness should be not less than the diameter and thickness of the appropriate round washer.

When tightened, a minimum of one complete thread should protrude from the nut.

Recommendations for dowels are given in **6.6.7**.

### 6.6.2 Effective cross-section

When assessing the effective cross-section of multiple bolt joints, all bolts that lie within a distance of two bolt diameters, measured parallel to the grain, from a given cross-section should be considered as occurring at that cross-section. Then the effective cross-section should be determined by deducting the net projected area of the bolt holes from the gross area of the cross-section.

### 6.6.3 Bolt spacing

Unless other values are shown to be satisfactory by test, the end distances, edge distances and spacings given in Table 81 should be observed for bolted joints.

### 6.6.4 Timber-to-timber joints

#### 6.6.4.1 *Basic single shear loads*

The basic loads for single bolts in a two-member timber joint, in which the load acts perpendicular to the axis of the bolt, and parallel or perpendicular to the grain of the timber, are given in Table 69, Table 70, Table 71, Table 72, Table 73 and Table 74. The basic loads appropriate to each shear plane in a three-member joint under the same conditions, are given in Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80. Separate loads are tabulated for long-, medium- and short-duration loads so no further duration of loading modification factors need be applied. Where the load is inclined at an angle $\alpha$ to the grain of the timber, the basic load, $F$, should be determined from the equation:

$$F = F_{\parallel} F_{\perp} / (F_{\parallel} \sin^2 \alpha + F_{\perp} \cos^2 \alpha)$$

where

$F_{\parallel}$ is the basic load parallel to the grain, obtained from Table 69, Table 70, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80;

$F_{\perp}$ is the basic load perpendicular to the grain, obtained from Table 69, Table 70, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80.

If the load acts at an angle to the axis of the bolt the component of the load perpendicular to the axis of the bolt should be not greater than the basic load given in Table 69, Table 70, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80, modified where appropriate by the above equation.
For two-member joints where parallel members are of unequal thickness, the load for the thinner member should be used. Where members of unequal thickness are joined at an angle, the basic load for each member should be determined and the smaller load used.

For three-member joints, the basic loads given in Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80 apply to joints where the outer members have the tabulated thickness and the inner member is twice as thick. For other thicknesses of inner or outer members, the load may be obtained by linear interpolation between the two adjacent tabulated thicknesses. If both inner and outer members have other thicknesses, the load should be taken as the lesser of the loads obtained by linear interpolation of the inner and outer member thicknesses separately.

The basic loads given in this clause for each bolt should be modified in accordance with **6.6.6** to determine the permissible load for a joint.

#### 6.6.4.2 *Basic multiple shear loads*

The basic load for a joint of more than three members should be taken as the sum of the basic loads for each shear plane, assuming that the joint consisted of a series of three-membered joints.

The basic loads given in this clause for each bolt should be modified in accordance with **6.6.6** to determine the permissible load for a joint.

### 6.6.5 Steel plate-to-timber joints

#### 6.6.5.1 *Steel plate*

Steel plates should have a minimum thickness of 2.5 mm or 0.3 times the bolt diameter, whichever is the greater, for the modification factors in **6.6.5.2** to apply.

The diameter of the holes in the timber and steel should be as close as practicable to the nominal diameter of the bolt, and in no case more than 2 mm larger.

#### 6.6.5.2 *Basic loads*

Where a steel component is bolted to a timber member loaded parallel to the grain, the basic load given in Table 69, Table 70, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80 or derived from Annex G should be multiplied by the steel-to-timber modification factor, $K_{46}$, which has the value 1.25.

No increase should be made to the basic load when the timber is loaded perpendicular to the grain.

The basic loads given in this clause for each bolt should be modified in accordance with **6.6.6** to determine the permissible load for a joint.

### 6.6.6 Permissible load for a joint

The permissible load for a bolted joint should be determined as the sum of the permissible loads for each bolt in the joint, where each permissible bolt load, $F_{adm}$, should be calculated from the equation:

$$F_{adm} = F \times K_{56} \times K_{57}$$

where the basic load for a bolt, $F$, is taken from **6.6.4** or **6.6.5.2** as appropriate:

$K_{56}$ is the modification factor for moisture content;

$K_{57}$ is the modification factor for the number of bolts in each line.

For moisture content:

$K_{56}$ = 1.0 for a joint in service classes 1 and 2;

$K_{56}$ = 0.7 for a joint made in timber of service class 3 and used in that service class;

$K_{56}$ = 0.4 for a joint made in timber of service class 3 and used in service classes 1 and 2.

For the number of bolts in each line:

where a number of bolts of the same diameter, acting in single or multiple shear, are symmetrically arranged in one or more lines parallel to the line of action of the load in a primarily axially loaded member in a structural framework (see **1.6.11**) then:

$$K_{57} = 1 - \frac{3(n-1)}{100} \qquad \text{for } n \leqslant 10$$

$$K_{57} = 0{,}7 \qquad \text{for } n > 10$$

where $n$ is the number of bolts in each line.

In all other loading cases where more than one bolt is used in a joint:

$$K_{57} = 1{,}0$$

### 6.6.7 Steel dowel joints

#### 6.6.7.1 *General*

The recommendations contained in **6.6.7** are applicable to plain steel dowels with a minimum tensile strength of 400 N/mm² and a minimum dowel diameter of 8 mm.

For the recommendations of **6.6.7** to apply, the tolerance on the specified dowel diameter should be $^{+0.1}_{0}$ mm and the dowels should be inserted in pre-bored holes in the timber members having a diameter not greater than that of the dowel itself. Where a dowel does not extend to the surface of the outer member, for example, for reasons of appearance, the thickness of the member for calculation purposes should be taken as the actual embedment length of the dowel.

Care should be taken to avoid axial forces being set up in dowelled joints as a result of asymmetrical, eccentric or oscillating loads.

Dowels may be used to form steel plate-to-timber joints in accordance with **6.6.5**. Where the steel plates form the outer members of the joint, then the steel plates should be secured in position (e.g. by threading the ends of the dowel and applying nuts) and it is essential that the dowels have a full bearing on the steel plate.

#### 6.6.7.2 *Effective cross-section*

When assessing the effective cross-section of multiple dowel joints, all dowels that lie within a distance of two dowel diameters measured parallel to the grain from a given cross-section should be considered as occurring at that cross-section. Then the effective cross-section should be determined by deducting the net projected area of the dowel holes from the gross area of the cross-section.

#### 6.6.7.3 *Dowel spacing*

The values relating to bolts in **6.6.3** apply.

#### 6.6.7.4 *Permissible load for a joint*

The permissible load for a dowelled joint should be calculated in accordance with **6.6.4**, **6.6.5** and **6.6.6** as appropriate using either the values given in Table 69, Table 70, Table 71, Table 72, Table 73 and Table 74 multiplied by the factor $K_{dowel}$ = 0.75 or the values given in Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80 or by calculation using Annex G.

**Table 69 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: C14 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.40 | 0.49 | 0.57 | 0.73 | 0.87 | 0.99 | 0.36 | 0.43 | 0.50 | 0.61 | 0.70 | 0.77 |
| | 22 | 0.55 | 0.67 | 0.79 | 1.01 | 1.20 | 1.36 | 0.50 | 0.59 | 0.68 | 0.84 | 0.96 | 1.06 |
| | 35 | 0.88 | 1.07 | 1.26 | 1.60 | 1.90 | 2.17 | 0.79 | 0.94 | 1.09 | 1.33 | 1.53 | 1.68 |
| | 44 | 1.10 | 1.35 | 1.58 | 2.01 | 2.39 | 2.73 | 0.99 | 1.19 | 1.37 | 1.67 | 1.92 | 2.11 |
| | 47 | 1.16 | 1.44 | 1.69 | 2.15 | 2.56 | 2.91 | 1.06 | 1.27 | 1.46 | 1.79 | 2.05 | 2.25 |
| | 60 | 1.31 | 1.80 | 2.15 | 2.74 | 3.26 | 3.72 | 1.21 | 1.62 | 1.88 | 2.28 | 2.62 | 2.88 |
| | 72 | 1.41 | 1.97 | 2.56 | 3.29 | 3.92 | 4.46 | 1.34 | 1.79 | 2.23 | 2.74 | 3.14 | 3.45 |
| | 97 | 1.41 | 2.19 | 2.97 | 4.42 | 5.28 | 6.01 | 1.34 | 2.05 | 2.65 | 3.69 | 4.23 | 4.65 |
| | 147 | 1.41 | 2.19 | 3.11 | 5.41 | 7.27 | 9.11 | 1.34 | 2.05 | 2.89 | 4.74 | 6.18 | 7.05 |
| Medium-term | 16 | 0.51 | 0.62 | 0.73 | 0.93 | 1.10 | 1.26 | 0.46 | 0.55 | 0.63 | 0.77 | 0.89 | 0.97 |
| | 22 | 0.70 | 0.85 | 1.00 | 1.28 | 1.52 | 1.73 | 0.63 | 0.75 | 0.87 | 1.06 | 1.22 | 1.34 |
| | 35 | 1.11 | 1.36 | 1.59 | 2.03 | 2.42 | 2.75 | 1.00 | 1.20 | 1.38 | 1.69 | 1.94 | 2.13 |
| | 44 | 1.33 | 1.71 | 2.00 | 2.55 | 3.04 | 3.46 | 1.23 | 1.51 | 1.73 | 2.12 | 2.43 | 2.68 |
| | 47 | 1.37 | 1.82 | 2.14 | 2.72 | 3.24 | 3.70 | 1.27 | 1.61 | 1.85 | 2.27 | 2.60 | 2.86 |
| | 60 | 1.56 | 2.13 | 2.73 | 3.48 | 4.14 | 4.72 | 1.44 | 1.94 | 2.36 | 2.89 | 3.32 | 3.65 |
| | 72 | 1.56 | 2.35 | 3.01 | 4.17 | 4.97 | 5.66 | 1.48 | 2.13 | 2.70 | 3.47 | 3.98 | 4.38 |
| | 97 | 1.56 | 2.42 | 3.44 | 5.19 | 6.69 | 7.63 | 1.48 | 2.27 | 3.17 | 4.54 | 5.37 | 5.90 |
| | 147 | 1.56 | 2.42 | 3.44 | 5.98 | 8.67 | 10.91 | 1.48 | 2.27 | 3.20 | 5.45 | 7.30 | 8.95 |
| Short- and very short-term | 16 | 0.58 | 0.71 | 0.83 | 1.06 | 1.26 | 1.43 | 0.52 | 0.62 | 0.72 | 0.88 | 1.01 | 1.11 |
| | 22 | 0.80 | 0.97 | 1.14 | 1.45 | 1.73 | 1.97 | 0.72 | 0.86 | 0.99 | 1.21 | 1.39 | 1.53 |
| | 35 | 1.27 | 1.55 | 1.82 | 2.31 | 2.75 | 3.14 | 1.14 | 1.37 | 1.57 | 1.92 | 2.21 | 2.43 |
| | 44 | 1.46 | 1.95 | 2.28 | 2.91 | 3.46 | 3.95 | 1.35 | 1.72 | 1.98 | 2.42 | 2.78 | 3.05 |
| | 47 | 1.51 | 2.08 | 2.44 | 3.11 | 3.70 | 4.22 | 1.39 | 1.83 | 2.11 | 2.58 | 2.96 | 3.26 |
| | 60 | 1.67 | 2.35 | 3.05 | 3.97 | 4.72 | 5.38 | 1.58 | 2.13 | 2.69 | 3.30 | 3.78 | 4.16 |
| | 72 | 1.67 | 2.58 | 3.32 | 4.76 | 5.66 | 6.46 | 1.58 | 2.36 | 2.98 | 3.96 | 4.54 | 5.00 |
| | 97 | 1.67 | 2.58 | 3.68 | 5.73 | 7.63 | 8.70 | 1.58 | 2.42 | 3.42 | 5.00 | 6.12 | 6.73 |
| | 147 | 1.67 | 2.58 | 3.68 | 6.38 | 9.63 | 12.02 | 1.58 | 2.42 | 3.42 | 5.82 | 8.08 | 9.96 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 70 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: C16/C18/C20/C22/TR20 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.43 | 0.52 | 0.61 | 0.78 | 0.93 | 1.06 | 0.39 | 0.46 | 0.53 | 0.65 | 0.75 | 0.82 |
| | 22 | 0.59 | 0.72 | 0.84 | 1.07 | 1.28 | 1.46 | 0.53 | 0.63 | 0.73 | 0.89 | 1.03 | 1.13 |
| | 35 | 0.94 | 1.14 | 1.34 | 1.71 | 2.03 | 2.32 | 0.84 | 1.01 | 1.16 | 1.42 | 1.63 | 1.79 |
| | 44 | 1.18 | 1.44 | 1.69 | 2.15 | 2.56 | 2.92 | 1.06 | 1.27 | 1.46 | 1.79 | 2.05 | 2.26 |
| | 47 | 1.22 | 1.54 | 1.80 | 2.30 | 2.73 | 3.12 | 1.13 | 1.36 | 1.56 | 1.91 | 2.19 | 2.41 |
| | 60 | 1.38 | 1.89 | 2.30 | 2.93 | 3.49 | 3.98 | 1.27 | 1.73 | 1.99 | 2.44 | 2.80 | 3.68 |
| | 72 | 1.46 | 2.07 | 2.68 | 3.52 | 4.19 | 4.77 | 1.39 | 1.88 | 2.39 | 2.93 | 3.36 | 3.69 |
| | 97 | 1.46 | 2.26 | 3.13 | 4.63 | 5.64 | 6.43 | 1.39 | 2.12 | 2.79 | 3.94 | 4.52 | 4.97 |
| | 147 | 1.46 | 2.26 | 3.22 | 5.59 | 7.65 | 9.74 | 1.39 | 2.12 | 2.99 | 5.00 | 6.49 | 7.54 |
| Medium-term | 16 | 0.54 | 0.66 | 0.78 | 0.99 | 1.18 | 1.35 | 0.49 | 0.59 | 0.67 | 0.82 | 0.95 | 1.04 |
| | 22 | 0.75 | 0.91 | 1.07 | 1.36 | 1.62 | 1.85 | 0.67 | 0.81 | 0.93 | 1.13 | 1.30 | 1.43 |
| | 35 | 1.19 | 1.45 | 1.70 | 2.17 | 2.58 | 2.94 | 1.07 | 1.28 | 1.47 | 1.80 | 2.07 | 2.28 |
| | 44 | 1.39 | 1.83 | 2.14 | 2.73 | 3.25 | 3.70 | 1.29 | 1.61 | 1.85 | 2.27 | 2.60 | 2.86 |
| | 47 | 1.44 | 1.95 | 2.29 | 2.91 | 3.47 | 3.95 | 1.33 | 1.72 | 1.98 | 2.42 | 2.78 | 3.06 |
| | 60 | 1.62 | 2.24 | 2.91 | 3.72 | 4.43 | 5.05 | 1.52 | 2.03 | 2.53 | 3.09 | 3.55 | 3.90 |
| | 72 | 1.62 | 2.48 | 3.16 | 4.46 | 5.31 | 6.06 | 1.53 | 2.24 | 2.84 | 3.71 | 4.26 | 4.68 |
| | 97 | 1.62 | 2.50 | 3.56 | 5.46 | 7.16 | 8.16 | 1.53 | 2.35 | 3.31 | 4.77 | 5.74 | 6.31 |
| | 147 | 1.62 | 2.50 | 3.56 | 6.18 | 9.14 | 11.46 | 1.53 | 2.35 | 3.31 | 5.64 | 7.68 | 9.52 |
| Short- and very short-term | 16 | 0.62 | 0.76 | 0.89 | 1.13 | 1.35 | 1.53 | 0.56 | 0.67 | 0.77 | 0.94 | 1.08 | 1.19 |
| | 22 | 0.85 | 1.04 | 1.22 | 1.55 | 1.85 | 2.11 | 0.77 | 0.92 | 1.06 | 1.29 | 1.48 | 1.63 |
| | 35 | 1.35 | 1.66 | 1.94 | 2.47 | 2.94 | 3.36 | 1.22 | 1.46 | 1.68 | 2.06 | 2.36 | 2.60 |
| | 44 | 1.54 | 2.08 | 2.44 | 3.11 | 3.70 | 4.22 | 1.42 | 1.84 | 2.11 | 2.59 | 2.97 | 3.26 |
| | 47 | 1.59 | 2.20 | 2.61 | 3.32 | 3.95 | 4.51 | 1.47 | 1.96 | 2.26 | 2.76 | 3.17 | 3.49 |
| | 60 | 1.73 | 2.47 | 3.19 | 4.24 | 5.05 | 5.75 | 1.64 | 2.24 | 2.88 | 3.53 | 4.05 | 4.45 |
| | 72 | 1.73 | 2.67 | 3.50 | 5.09 | 6.06 | 6.90 | 1.64 | 2.19 | 3.13 | 4.23 | 4.85 | 5.34 |
| | 97 | 1.73 | 2.67 | 3.80 | 6.03 | 8.16 | 9.30 | 1.64 | 2.51 | 3.53 | 5.25 | 6.54 | 7.19 |
| | 147 | 1.73 | 2.67 | 3.80 | 6.60 | 10.07 | 12.64 | 1.64 | 2.51 | 3.53 | 6.02 | 8.51 | 10.45 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 71 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: C24 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.48 | 0.59 | 0.69 | 0.88 | 1.05 | 1.20 | 0.43 | 0.52 | 0.60 | 0.73 | 0.84 | 0.93 |
| | 22 | 0.66 | 0.81 | 0.95 | 1.21 | 1.44 | 1.65 | 0.60 | 0.72 | 0.82 | 1.01 | 1.16 | 1.27 |
| | 35 | 1.06 | 1.29 | 1.52 | 1.93 | 2.30 | 2.62 | 0.95 | 1.14 | 1.31 | 1.61 | 1.84 | 2.03 |
| | 44 | 1.29 | 1.62 | 1.91 | 2.43 | 2.89 | 3.29 | 1.20 | 1.43 | 1.65 | 2.02 | 2.32 | 2.55 |
| | 47 | 1.33 | 1.74 | 2.04 | 2.59 | 3.09 | 3.52 | 1.23 | 1.53 | 1.76 | 2.16 | 2.47 | 2.72 |
| | 60 | 1.52 | 2.07 | 2.60 | 3.31 | 3.94 | 4.49 | 1.40 | 1.89 | 2.25 | 2.75 | 3.16 | 3.47 |
| | 72 | 1.55 | 2.28 | 2.93 | 3.97 | 4.73 | 5.39 | 1.47 | 2.06 | 2.64 | 3.30 | 3.79 | 4.17 |
| | 97 | 1.55 | 2.40 | 3.42 | 5.05 | 6.37 | 7.26 | 1.47 | 2.26 | 3.07 | 4.43 | 5.11 | 5.62 |
| | 147 | 1.55 | 2.40 | 3.42 | 5.94 | 8.40 | 10.63 | 1.47 | 2.26 | 3.18 | 5.42 | 7.09 | 8.51 |
| Medium-term | 16 | 0.61 | 0.75 | 0.88 | 1.12 | 1.33 | 1.52 | 0.55 | 0.66 | 0.76 | 0.93 | 1.07 | 1.18 |
| | 22 | 0.84 | 1.03 | 1.21 | 1.54 | 1.83 | 2.09 | 0.76 | 0.91 | 1.05 | 1.28 | 1.47 | 1.62 |
| | 35 | 1.34 | 1.64 | 1.92 | 2.45 | 2.92 | 3.32 | 1.21 | 1.45 | 1.66 | 2.04 | 2.34 | 2.57 |
| | 44 | 1.52 | 2.06 | 2.42 | 3.08 | 3.66 | 4.18 | 1.41 | 1.82 | 2.09 | 2.56 | 2.94 | 3.23 |
| | 47 | 1.58 | 2.18 | 2.58 | 3.29 | 3.91 | 4.46 | 1.46 | 1.94 | 2.23 | 2.74 | 3.14 | 3.45 |
| | 60 | 1.72 | 2.45 | 3.17 | 4.20 | 5.00 | 5.70 | 1.63 | 2.23 | 2.85 | 3.49 | 4.01 | 4.41 |
| | 72 | 1.72 | 2.66 | 3.47 | 5.04 | 6.00 | 6.84 | 1.63 | 2.47 | 3.11 | 4.19 | 4.81 | 5.29 |
| | 97 | 1.72 | 2.66 | 3.78 | 5.99 | 8.08 | 9.21 | 1.63 | 2.49 | 3.52 | 5.21 | 6.48 | 7.13 |
| | 147 | 1.72 | 2.66 | 3.78 | 6.57 | 10.02 | 12.55 | 1.63 | 2.49 | 3.52 | 5.99 | 8.45 | 10.38 |
| Short- and very short-term | 16 | 0.70 | 0.85 | 1.00 | 1.28 | 1.52 | 1.73 | 0.63 | 0.75 | 0.87 | 1.06 | 1.22 | 1.34 |
| | 22 | 0.96 | 1.17 | 1.38 | 1.75 | 2.09 | 2.38 | 0.86 | 1.04 | 1.19 | 1.46 | 1.67 | 1.84 |
| | 35 | 1.51 | 1.87 | 2.19 | 2.79 | 3.32 | 3.79 | 1.38 | 1.65 | 1.90 | 2.32 | 2.66 | 2.93 |
| | 44 | 1.69 | 2.33 | 2.76 | 3.51 | 4.18 | 4.76 | 1.55 | 2.07 | 2.38 | 2.92 | 3.35 | 3.68 |
| | 47 | 1.75 | 2.39 | 2.95 | 3.75 | 4.46 | 5.09 | 1.61 | 2.19 | 2.55 | 3.12 | 3.58 | 3.94 |
| | 60 | 1.84 | 2.72 | 3.49 | 4.79 | 5.70 | 6.49 | 1.74 | 2.46 | 3.14 | 3.98 | 4.57 | 5.02 |
| | 72 | 1.84 | 2.84 | 3.85 | 5.73 | 6.84 | 7.79 | 1.74 | 2.66 | 3.43 | 4.78 | 5.48 | 6.03 |
| | 97 | 1.84 | 2.84 | 4.04 | 6.63 | 8.92 | 10.50 | 1.74 | 2.66 | 3.76 | 5.75 | 7.38 | 8.12 |
| | 147 | 1.84 | 2.84 | 4.04 | 7.01 | 10.70 | 13.88 | 1.74 | 2.66 | 3.76 | 6.40 | 9.38 | 11.42 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 72 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: TR26/C27/C30 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.51 | 0.62 | 0.73 | 0.93 | 1.11 | 1.27 | 0.46 | 0.55 | 0.63 | 0.78 | 0.89 | 0.98 |
| | 22 | 0.70 | 0.86 | 1.01 | 1.28 | 1.53 | 1.74 | 0.63 | 0.76 | 0.87 | 1.07 | 1.22 | 1.35 |
| | 35 | 1.12 | 1.37 | 1.60 | 2.04 | 2.43 | 2.77 | 1.01 | 1.20 | 1.39 | 1.70 | 1.95 | 2.14 |
| | 44 | 1.34 | 1.72 | 2.02 | 2.56 | 3.05 | 3.48 | 1.25 | 1.51 | 1.74 | 2.13 | 2.45 | 2.69 |
| | 47 | 1.39 | 1.83 | 2.15 | 2.74 | 3.26 | 3.72 | 1.28 | 1.62 | 1.86 | 2.28 | 2.61 | 2.88 |
| | 60 | 1.59 | 2.15 | 2.75 | 3.50 | 4.16 | 4.75 | 1.46 | 1.96 | 2.38 | 2.91 | 3.34 | 3.67 |
| | 72 | 1.60 | 2.38 | 3.05 | 4.20 | 5.00 | 5.70 | 1.52 | 2.15 | 2.74 | 3.49 | 4.01 | 4.41 |
| | 97 | 1.60 | 2.47 | 3.52 | 5.27 | 6.73 | 7.67 | 1.52 | 2.32 | 3.21 | 4.61 | 5.40 | 5.94 |
| | 147 | 1.60 | 2.47 | 3.52 | 6.11 | 8.77 | 11.06 | 1.52 | 2.32 | 3.27 | 5.57 | 7.40 | 9.00 |
| Medium-term | 16 | 0.65 | 0.79 | 0.93 | 1.18 | 1.41 | 1.61 | 0.58 | 0.70 | 0.80 | 0.98 | 1.13 | 1.24 |
| | 22 | 0.89 | 1.09 | 1.28 | 1.63 | 1.94 | 2.21 | 0.80 | 0.96 | 1.11 | 1.35 | 1.55 | 1.71 |
| | 35 | 1.42 | 1.73 | 2.03 | 2.59 | 3.08 | 3.51 | 1.28 | 1.53 | 1.76 | 2.15 | 2.47 | 2.72 |
| | 44 | 1.59 | 2.18 | 2.56 | 3.25 | 3.87 | 4.42 | 1.47 | 1.92 | 2.21 | 2.71 | 3.11 | 3.42 |
| | 47 | 1.65 | 2.27 | 2.73 | 3.48 | 4.14 | 4.72 | 1.52 | 2.05 | 2.36 | 2.89 | 3.32 | 3.65 |
| | 60 | 1.77 | 2.56 | 3.30 | 4.44 | 5.28 | 6.02 | 1.68 | 2.32 | 2.98 | 3.69 | 4.24 | 4.66 |
| | 72 | 1.77 | 2.73 | 3.63 | 5.33 | 6.34 | 7.23 | 1.68 | 2.56 | 3.24 | 4.43 | 5.08 | 5.59 |
| | 97 | 1.77 | 2.73 | 3.89 | 6.25 | 8.46 | 9.74 | 1.68 | 2.56 | 3.62 | 5.43 | 6.85 | 7.53 |
| | 147 | 1.77 | 2.73 | 3.89 | 6.75 | 10.30 | 13.09 | 1.68 | 2.56 | 3.62 | 6.16 | 8.83 | 10.81 |
| Short- and very short-term | 16 | 0.74 | 0.90 | 1.06 | 1.35 | 1.61 | 1.83 | 0.66 | 0.80 | 0.92 | 1.12 | 1.29 | 1.42 |
| | 22 | 1.02 | 1.24 | 1.46 | 1.85 | 2.21 | 2.52 | 0.91 | 1.10 | 1.26 | 1.54 | 1.77 | 1.95 |
| | 35 | 1.57 | 1.98 | 2.32 | 2.95 | 3.51 | 4.00 | 1.45 | 1.74 | 2.00 | 2.46 | 2.82 | 3.10 |
| | 44 | 1.76 | 2.42 | 2.91 | 3.71 | 4.42 | 5.03 | 1.62 | 2.19 | 2.52 | 3.09 | 3.54 | 3.89 |
| | 47 | 1.83 | 2.49 | 3.11 | 3.96 | 4.72 | 5.38 | 1.68 | 2.28 | 2.69 | 3.30 | 3.78 | 4.16 |
| | 60 | 1.89 | 2.84 | 3.64 | 5.06 | 6.02 | 6.87 | 1.79 | 2.57 | 3.27 | 4.21 | 4.83 | 5.31 |
| | 72 | 1.89 | 2.92 | 4.02 | 5.96 | 7.23 | 8.24 | 1.79 | 2.74 | 3.59 | 5.05 | 5.79 | 6.37 |
| | 97 | 1.89 | 2.92 | 4.15 | 6.93 | 9.29 | 11.10 | 1.79 | 2.74 | 3.86 | 6.00 | 7.81 | 8.59 |
| | 147 | 1.89 | 2.92 | 4.15 | 7.21 | 11.00 | 14.50 | 1.79 | 2.74 | 3.86 | 6.58 | 9.81 | 11.90 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 73 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: D30/D35/D40 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.73 | 0.89 | 1.05 | 1.34 | 1.59 | 1.81 | 0.73 | 0.89 | 1.05 | 1.34 | 1.59 | 1.81 |
| | 22 | 1.01 | 1.23 | 1.44 | 1.84 | 2.19 | 2.49 | 1.01 | 1.23 | 1.44 | 1.84 | 2.19 | 2.49 |
| | 35 | 1.58 | 1.96 | 2.30 | 2.92 | 3.48 | 3.97 | 1.58 | 1.96 | 2.30 | 2.92 | 3.48 | 3.97 |
| | 44 | 1.76 | 2.43 | 2.89 | 3.67 | 4.37 | 4.99 | 1.76 | 2.43 | 2.89 | 3.67 | 4.37 | 4.99 |
| | 47 | 1.83 | 2.50 | 3.08 | 3.92 | 4.67 | 5.33 | 1.83 | 2.50 | 3.08 | 3.92 | 4.67 | 5.33 |
| | 60 | 1.91 | 2.84 | 3.65 | 5.01 | 5.96 | 6.80 | 1.91 | 2.84 | 3.65 | 5.01 | 5.96 | 6.80 |
| | 72 | 1.91 | 2.96 | 4.02 | 5.98 | 7.16 | 8.16 | 1.91 | 2.96 | 4.02 | 5.98 | 7.16 | 8.16 |
| | 97 | 1.91 | 2.96 | 4.21 | 6.93 | 9.32 | 10.99 | 1.91 | 2.96 | 4.21 | 6.93 | 9.32 | 10.99 |
| | 147 | 1.91 | 2.96 | 4.21 | 7.31 | 11.14 | 14.50 | 1.91 | 2.96 | 4.21 | 7.31 | 11.14 | 14.50 |
| Medium-term | 16 | 0.93 | 1.14 | 1.33 | 1.70 | 2.02 | 2.30 | 0.93 | 1.14 | 1.33 | 1.70 | 2.02 | 2.30 |
| | 22 | 1.28 | 1.56 | 1.83 | 2.33 | 2.77 | 3.16 | 1.28 | 1.56 | 1.83 | 2.33 | 2.77 | 3.16 |
| | 35 | 1.86 | 2.48 | 2.91 | 3.71 | 4.41 | 5.03 | 1.86 | 2.48 | 2.91 | 3.71 | 4.41 | 5.03 |
| | 44 | 2.11 | 2.86 | 3.66 | 4.66 | 5.55 | 6.33 | 2.11 | 2.86 | 3.66 | 4.66 | 5.55 | 6.33 |
| | 47 | 2.12 | 2.96 | 3.84 | 4.98 | 5.93 | 6.76 | 2.12 | 2.96 | 3.84 | 4.98 | 5.93 | 6.76 |
| | 60 | 2.12 | 3.27 | 4.33 | 6.36 | 7.57 | 8.63 | 2.12 | 3.27 | 4.33 | 6.36 | 7.57 | 8.63 |
| | 72 | 2.12 | 3.27 | 4.65 | 7.03 | 9.08 | 10.35 | 2.12 | 3.27 | 4.65 | 7.03 | 9.08 | 10.35 |
| | 97 | 2.12 | 3.27 | 4.65 | 8.08 | 11.00 | 13.95 | 2.12 | 3.27 | 4.65 | 8.08 | 11.00 | 13.95 |
| | 147 | 2.12 | 3.27 | 4.65 | 8.08 | 12.33 | 17.30 | 2.12 | 3.27 | 4.65 | 8.08 | 12.33 | 17.30 |
| Short- and very short-term | 16 | 1.06 | 1.29 | 1.52 | 1.93 | 2.30 | 2.62 | 1.06 | 1.29 | 1.52 | 1.93 | 2.30 | 2.62 |
| | 22 | 1.46 | 1.78 | 2.09 | 2.66 | 3.16 | 3.61 | 1.46 | 1.78 | 2.09 | 2.66 | 3.16 | 3.61 |
| | 35 | 2.05 | 2.83 | 3.32 | 4.23 | 5.03 | 5.74 | 2.05 | 2.83 | 3.32 | 4.23 | 5.03 | 5.74 |
| | 44 | 2.26 | 3.16 | 4.10 | 5.31 | 6.33 | 7.21 | 2.26 | 3.16 | 4.10 | 5.31 | 6.33 | 7.21 |
| | 47 | 2.26 | 3.28 | 4.22 | 5.68 | 6.76 | 7.70 | 2.26 | 3.28 | 4.22 | 5.68 | 6.76 | 7.70 |
| | 60 | 2.26 | 3.49 | 4.81 | 7.12 | 8.63 | 9.83 | 2.26 | 3.49 | 4.81 | 7.12 | 8.63 | 9.83 |
| | 72 | 2.26 | 3.49 | 4.97 | 7.76 | 10.35 | 11.80 | 2.26 | 3.49 | 4.97 | 7.76 | 10.35 | 11.80 |
| | 97 | 2.26 | 3.49 | 4.97 | 8.63 | 12.17 | 15.41 | 2.26 | 3.49 | 4.97 | 8.63 | 12.17 | 15.41 |
| | 147 | 2.26 | 3.49 | 4.97 | 8.63 | 13.16 | 18.47 | 2.26 | 3.49 | 4.97 | 8.63 | 13.16 | 18.47 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 74 — Basic single shear loads in kiloNewtons (kN) for one 4.6 grade steel bolt in a two member timber-to-timber joint: D50/D60/D70 timber**

| Load duration | Minimum member thickness | Direction of loading | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Parallel to grain | | | | | | Perpendicular to grain | | | | | |
| | | Bolt diameter | | | | | | Bolt diameter | | | | | |
| | mm | M8 | M10 | M12 | M16 | M20 | M24 | M8 | M10 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.90 | 1.10 | 1.29 | 1.64 | 1.95 | 2.22 | 0.90 | 1.10 | 1.29 | 1.64 | 1.95 | 2.22 |
| | 22 | 1.23 | 1.51 | 1.77 | 2.25 | 2.68 | 3.06 | 1.23 | 1.51 | 1.77 | 2.25 | 2.68 | 3.16 |
| | 35 | 1.83 | 2.40 | 2.82 | 3.58 | 4.27 | 4.86 | 1.83 | 2.40 | 2.82 | 3.58 | 4.27 | 4.86 |
| | 44 | 2.07 | 2.82 | 3.54 | 4.51 | 5.36 | 6.12 | 2.07 | 2.82 | 3.54 | 4.51 | 5.36 | 6.12 |
| | 47 | 2.12 | 2.91 | 3.78 | 4.81 | 5.73 | 6.53 | 2.12 | 2.91 | 3.78 | 4.81 | 5.73 | 6.53 |
| | 60 | 2.12 | 3.27 | 4.26 | 6.14 | 7.31 | 8.34 | 2.12 | 3.27 | 4.26 | 6.14 | 7.31 | 8.34 |
| | 72 | 2.12 | 3.27 | 4.66 | 6.92 | 8.78 | 10.01 | 2.12 | 3.27 | 4.66 | 6.92 | 8.78 | 10.31 |
| | 97 | 2.12 | 3.27 | 4.66 | 8.09 | 10.82 | 13.48 | 2.12 | 3.27 | 4.66 | 8.09 | 10.82 | 13.48 |
| | 147 | 2.12 | 3.27 | 4.66 | 8.09 | 12.34 | 17.06 | 2.12 | 3.27 | 4.66 | 8.09 | 12.34 | 17.06 |
| Medium-term | 16 | 1.14 | 1.39 | 1.63 | 2.08 | 2.47 | 2.82 | 1.14 | 1.39 | 1.63 | 2.08 | 2.47 | 2.82 |
| | 22 | 1.57 | 1.91 | 2.25 | 2.86 | 3.40 | 3.88 | 1.57 | 1.91 | 2.25 | 2.86 | 3.40 | 3.88 |
| | 35 | 2.17 | 2.99 | 3.57 | 4.55 | 5.41 | 6.17 | 2.17 | 2.99 | 3.57 | 4.55 | 5.41 | 6.17 |
| | 44 | 2.34 | 3.34 | 4.32 | 5.72 | 6.81 | 7.76 | 2.34 | 3.34 | 4.32 | 5.72 | 6.81 | 7.76 |
| | 47 | 2.34 | 3.47 | 4.46 | 6.11 | 7.27 | 8.29 | 2.34 | 3.47 | 4.46 | 6.11 | 7.27 | 8.29 |
| | 60 | 2.34 | 3.62 | 5.10 | 7.50 | 9.28 | 10.58 | 2.34 | 3.62 | 5.10 | 7.50 | 9.28 | 10.58 |
| | 72 | 2.34 | 3.62 | 5.15 | 8.21 | 11.14 | 12.70 | 2.34 | 3.62 | 5.15 | 8.21 | 11.14 | 12.70 |
| | 97 | 2.34 | 3.62 | 5.15 | 8.95 | 12.89 | 16.24 | 2.34 | 3.62 | 5.15 | 8.95 | 12.89 | 16.54 |
| | 147 | 2.34 | 3.62 | 5.15 | 8.95 | 13.65 | 19.16 | 2.34 | 3.62 | 5.15 | 8.95 | 13.65 | 19.16 |
| Short- and very short-term | 16 | 1.30 | 1.59 | 1.86 | 2.37 | 2.82 | 3.22 | 1.30 | 1.59 | 1.86 | 2.37 | 2.82 | 3.22 |
| | 22 | 1.78 | 2.18 | 2.56 | 3.26 | 3.88 | 4.42 | 1.78 | 2.18 | 2.56 | 3.26 | 3.88 | 4.42 |
| | 35 | 2.41 | 3.29 | 4.07 | 5.18 | 6.17 | 7.04 | 2.41 | 3.29 | 4.07 | 5.18 | 6.17 | 7.04 |
| | 44 | 2.50 | 3.71 | 4.76 | 6.52 | 7.76 | 8.84 | 2.50 | 3.71 | 4.76 | 6.52 | 7.76 | 8.84 |
| | 47 | 2.50 | 3.86 | 4.92 | 6.96 | 8.29 | 9.45 | 2.50 | 3.86 | 4.92 | 6.96 | 8.29 | 9.45 |
| | 60 | 2.50 | 3.87 | 5.50 | 8.26 | 10.58 | 12.06 | 2.50 | 3.87 | 5.50 | 8.26 | 10.58 | 12.06 |
| | 72 | 2.50 | 3.87 | 5.50 | 9.10 | 12.22 | 14.47 | 2.50 | 3.87 | 5.50 | 9.10 | 12.22 | 14.47 |
| | 97 | 2.50 | 3.87 | 5.50 | 9.56 | 14.31 | 17.89 | 2.50 | 3.87 | 5.50 | 9.56 | 14.31 | 17.89 |
| | 147 | 2.50 | 3.87 | 5.50 | 9.56 | 14.58 | 20.46 | 2.50 | 3.87 | 5.50 | 9.56 | 14.58 | 20.46 |

NOTE 1 The value for 4.6 grade steel dowels should be taken as 0.75 times the tabulated value. There is some advantage in using Annex G where member thickness divided by dowel diameter is greater than 8 for softwoods.

NOTE 2 The spacing of bolts and dowels parallel to the grain is 4 times the bolt diameter. Increased values for spacings up to 7 times the diameter can be obtained using Annex G.

NOTE 3 The perpendicular to the grain values are for both pieces loaded 90° to grain.

**Table 75 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: C14 timber**

| Load duration | Minimum outer member thickness [a] | C14 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.72 | 1.04 | 1.32 | 1.57 | 1.79 | 0.65 | 0.90 | 1.10 | 1.26 | 1.39 |
| | 22 | 0.99 | 1.43 | 1.82 | 2.16 | 2.46 | 0.90 | 1.23 | 1.51 | 1.73 | 1.91 |
| | 35 | 1.06 | 2.21 | 2.89 | 3.44 | 3.92 | 0.99 | 1.96 | 2.41 | 2.76 | 3.04 |
| | 44 | 1.13 | 2.25 | 3.63 | 4.32 | 4.93 | 1.06 | 2.08 | 3.02 | 3.47 | 3.82 |
| | 47 | 1.16 | 2.27 | 3.84 | 4.62 | 5.26 | 1.08 | 2.09 | 3.23 | 3.71 | 4.08 |
| | 60 | 1.31 | 2.40 | 3.91 | 5.85 | 6.72 | 1.21 | 2.19 | 3.53 | 4.73 | 5.20 |
| | 72 | 1.42 | 2.56 | 4.03 | 5.92 | 8.06 | 1.34 | 2.31 | 3.61 | 5.26 | 6.24 |
| | 97 | 1.42 | 2.96 | 4.42 | 6.22 | 8.39 | 1.35 | 2.65 | 3.90 | 5.44 | 7.28 |
| | 147 | 1.42 | 3.12 | 5.42 | 7.26 | 9.31 | 1.35 | 2.90 | 4.73 | 6.18 | 7.85 |
| Medium-term | 16 | 0.93 | 1.33 | 1.70 | 2.02 | 2.30 | 0.84 | 1.15 | 1.41 | 1.62 | 1.78 |
| | 22 | 1.13 | 1.83 | 2.33 | 2.78 | 3.17 | 1.06 | 1.59 | 1.94 | 2.23 | 2.45 |
| | 35 | 1.23 | 2.48 | 3.71 | 4.42 | 5.04 | 1.15 | 2.30 | 3.09 | 3.55 | 3.90 |
| | 44 | 1.34 | 2.56 | 4.29 | 5.56 | 6.34 | 1.24 | 2.36 | 3.89 | 4.46 | 4.91 |
| | 47 | 1.38 | 2.60 | 4.31 | 5.94 | 6.77 | 1.28 | 2.38 | 3.91 | 4.76 | 5.24 |
| | 60 | 1.58 | 2.80 | 4.45 | 6.57 | 8.64 | 1.46 | 2.54 | 4.00 | 5.84 | 6.69 |
| | 72 | 1.58 | 3.04 | 4.66 | 6.71 | 9.20 | 1.50 | 2.73 | 4.15 | 5.92 | 8.03 |
| | 97 | 1.58 | 3.47 | 5.24 | 7.22 | 9.58 | 1.50 | 3.20 | 4.59 | 6.26 | 8.24 |
| | 147 | 1.58 | 3.47 | 6.03 | 8.74 | 11.00 | 1.50 | 3.23 | 5.51 | 7.37 | 9.18 |
| Short-term and very short-term | 16 | 1.05 | 1.50 | 1.91 | 2.27 | 2.59 | 0.94 | 1.30 | 1.59 | 1.82 | 2.01 |
| | 22 | 1.20 | 2.06 | 2.63 | 3.13 | 3.56 | 1.13 | 1.79 | 2.19 | 2.51 | 2.76 |
| | 35 | 1.33 | 2.65 | 4.18 | 4.97 | 5.67 | 1.24 | 2.45 | 3.48 | 3.99 | 4.39 |
| | 44 | 1.46 | 2.75 | 4.57 | 6.25 | 7.13 | 1.35 | 2.52 | 4.14 | 5.02 | 5.52 |
| | 47 | 1.51 | 2.80 | 4.59 | 6.68 | 7.61 | 1.39 | 2.56 | 4.16 | 5.36 | 5.90 |
| | 60 | 1.67 | 3.04 | 4.78 | 7.00 | 9.70 | 1.59 | 2.75 | 4.28 | 6.22 | 7.53 |
| | 72 | 1.67 | 3.32 | 5.04 | 7.19 | 9.80 | 1.59 | 2.98 | 4.47 | 6.33 | 8.55 |
| | 97 | 1.67 | 3.69 | 5.72 | 7.82 | 10.30 | 1.59 | 3.43 | 4.99 | 6.75 | 8.82 |
| | 147 | 1.67 | 3.69 | 6.40 | 9.61 | 12.01 | 1.59 | 3.43 | 5.84 | 8.07 | 9.96 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 76 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: C16/18/22 timber**

| Load duration | Minimum outer member thickness [a] | C16/18/22 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.77 | 1.11 | 1.41 | 1.68 | 1.91 | 0.70 | 0.96 | 1.18 | 1.35 | 1.48 |
| | 22 | 1.04 | 1.52 | 1.94 | 2.31 | 2.63 | 0.96 | 1.32 | 1.62 | 1.85 | 2.04 |
| | 35 | 1.10 | 2.29 | 3.09 | 3.67 | 4.19 | 1.03 | 2.10 | 2.57 | 2.95 | 3.24 |
| | 44 | 1.19 | 2.34 | 3.88 | 4.62 | 5.26 | 1.10 | 2.16 | 3.23 | 3.71 | 4.08 |
| | 47 | 1.22 | 2.36 | 3.97 | 4.93 | 5.62 | 1.13 | 2.17 | 3.45 | 3.96 | 4.36 |
| | 60 | 1.38 | 2.50 | 4.06 | 6.06 | 7.18 | 1.27 | 2.28 | 3.66 | 5.06 | 5.56 |
| | 72 | 1.47 | 2.68 | 4.20 | 6.14 | 8.49 | 1.39 | 2.42 | 3.76 | 5.45 | 6.67 |
| | 97 | 1.47 | 3.12 | 4.63 | 6.48 | 8.72 | 1.39 | 2.79 | 4.08 | 5.66 | 7.55 |
| | 147 | 1.47 | 3.23 | 5.60 | 7.63 | 9.74 | 1.39 | 3.00 | 4.99 | 6.48 | 8.20 |
| Medium-term | 16 | 0.99 | 1.43 | 1.81 | 2.16 | 2.46 | 0.90 | 1.23 | 1.51 | 1.73 | 1.91 |
| | 22 | 1.17 | 1.96 | 2.49 | 2.97 | 3.38 | 1.10 | 1.70 | 2.08 | 2.38 | 2.62 |
| | 35 | 1.28 | 2.58 | 3.97 | 4.72 | 5.38 | 1.20 | 2.38 | 3.31 | 3.79 | 4.17 |
| | 44 | 1.40 | 2.67 | 4.44 | 5.94 | 6.77 | 1.30 | 2.45 | 4.04 | 4.77 | 5.24 |
| | 47 | 1.45 | 2.71 | 4.47 | 6.34 | 7.23 | 1.34 | 2.48 | 4.05 | 5.09 | 5.60 |
| | 60 | 1.63 | 2.94 | 4.63 | 6.81 | 9.23 | 1.54 | 2.66 | 4.16 | 6.05 | 7.15 |
| | 72 | 1.63 | 3.19 | 4.87 | 6.98 | 9.53 | 1.55 | 2.87 | 4.32 | 6.15 | 8.33 |
| | 97 | 1.63 | 3.59 | 5.51 | 7.55 | 9.97 | 1.55 | 3.34 | 4.81 | 6.53 | 8.56 |
| | 147 | 1.63 | 3.59 | 6.24 | 9.22 | 11.55 | 1.55 | 3.34 | 5.69 | 7.76 | 9.61 |
| Short-term and very short-term | 16 | 1.12 | 1.60 | 2.04 | 2.43 | 2.77 | 1.01 | 1.39 | 1.70 | 1.95 | 2.15 |
| | 22 | 1.24 | 2.20 | 2.81 | 3.34 | 3.81 | 1.17 | 1.91 | 2.34 | 2.68 | 2.95 |
| | 35 | 1.39 | 2.75 | 4.46 | 5.31 | 6.06 | 1.29 | 2.54 | 3.72 | 4.27 | 4.69 |
| | 44 | 1.53 | 2.87 | 4.73 | 6.68 | 7.62 | 1.42 | 2.63 | 4.29 | 5.36 | 5.90 |
| | 47 | 1.59 | 2.92 | 4.77 | 7.14 | 8.13 | 1.47 | 2.67 | 4.31 | 5.73 | 6.30 |
| | 60 | 1.73 | 3.19 | 4.98 | 7.27 | 10.04 | 1.64 | 2.88 | 4.46 | 6.44 | 8.05 |
| | 72 | 1.73 | 3.49 | 5.27 | 7.49 | 10.17 | 1.64 | 3.13 | 4.66 | 6.58 | 8.86 |
| | 97 | 1.73 | 3.81 | 6.02 | 8.18 | 10.73 | 1.64 | 3.54 | 5.25 | 7.05 | 9.18 |
| | 147 | 1.73 | 3.81 | 6.62 | 10.09 | 12.62 | 1.64 | 3.54 | 6.04 | 8.50 | 10.45 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 77 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: C24 timber**

| Load duration | Minimum outer member thickness [a] | C24 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.87 | 1.25 | 1.59 | 1.89 | 2.16 | 0.79 | 1.08 | 1.33 | 1.52 | 1.67 |
| | 22 | 1.11 | 1.72 | 2.19 | 2.61 | 2.97 | 1.05 | 1.49 | 1.82 | 2.09 | 2.30 |
| | 35 | 1.19 | 2.44 | 3.48 | 4.14 | 4.72 | 1.12 | 2.26 | 2.90 | 3.33 | 3.66 |
| | 44 | 1.29 | 2.51 | 4.22 | 5.21 | 5.94 | 1.20 | 2.31 | 3.65 | 4.19 | 4.61 |
| | 47 | 1.33 | 2.54 | 4.23 | 5.57 | 6.34 | 1.23 | 2.33 | 3.85 | 4.47 | 4.92 |
| | 60 | 1.51 | 2.71 | 4.35 | 6.45 | 8.10 | 1.40 | 2.47 | 3.92 | 5.71 | 6.28 |
| | 72 | 1.56 | 2.92 | 4.53 | 6.57 | 9.04 | 1.48 | 2.64 | 4.04 | 5.82 | 7.54 |
| | 97 | 1.56 | 3.43 | 5.05 | 7.01 | 9.35 | 1.48 | 3.07 | 4.43 | 6.10 | 8.08 |
| | 147 | 1.56 | 3.43 | 5.95 | 8.38 | 10.61 | 1.48 | 3.19 | 5.43 | 7.09 | 8.89 |
| Medium-term | 16 | 1.12 | 1.61 | 2.05 | 2.44 | 2.78 | 1.01 | 1.39 | 1.71 | 1.96 | 2.15 |
| | 22 | 1.25 | 2.21 | 2.81 | 3.35 | 3.82 | 1.18 | 1.92 | 2.35 | 2.69 | 2.96 |
| | 35 | 1.39 | 2.75 | 4.48 | 5.33 | 6.07 | 1.30 | 2.54 | 3.73 | 4.28 | 4.71 |
| | 44 | 1.54 | 2.87 | 4.74 | 6.70 | 7.64 | 1.42 | 2.63 | 4.30 | 5.38 | 5.92 |
| | 47 | 1.59 | 2.93 | 4.77 | 7.15 | 8.16 | 1.47 | 2.67 | 4.32 | 5.75 | 6.32 |
| | 60 | 1.73 | 3.20 | 4.99 | 7.28 | 10.05 | 1.65 | 2.89 | 4.47 | 6.45 | 8.07 |
| | 72 | 1.73 | 3.50 | 5.28 | 7.50 | 10.18 | 1.65 | 3.14 | 4.68 | 6.59 | 8.87 |
| | 97 | 1.73 | 3.81 | 6.04 | 8.20 | 10.75 | 1.65 | 3.55 | 5.26 | 7.07 | 9.20 |
| | 147 | 1.73 | 3.81 | 6.63 | 10.10 | 12.65 | 1.65 | 3.55 | 6.05 | 8.53 | 10.48 |
| Short-term and very short-term | 16 | 1.26 | 1.81 | 2.30 | 2.74 | 3.12 | 1.14 | 1.57 | 1.92 | 2.20 | 2.42 |
| | 22 | 1.33 | 2.49 | 3.17 | 3.77 | 4.30 | 1.26 | 2.16 | 2.64 | 3.03 | 3.33 |
| | 35 | 1.51 | 2.95 | 4.98 | 5.99 | 6.83 | 1.40 | 2.72 | 4.20 | 4.82 | 5.30 |
| | 44 | 1.68 | 3.10 | 5.06 | 7.54 | 8.59 | 1.55 | 2.83 | 4.58 | 6.06 | 6.66 |
| | 47 | 1.75 | 3.16 | 5.10 | 7.60 | 9.18 | 1.61 | 2.88 | 4.61 | 6.47 | 7.12 |
| | 60 | 1.84 | 3.48 | 5.38 | 7.78 | 10.69 | 1.75 | 3.14 | 4.80 | 6.88 | 9.08 |
| | 72 | 1.84 | 3.84 | 5.72 | 8.06 | 10.88 | 1.75 | 3.43 | 5.05 | 7.06 | 9.45 |
| | 97 | 1.84 | 4.05 | 6.62 | 8.91 | 11.60 | 1.75 | 3.77 | 5.75 | 7.65 | 9.88 |
| | 147 | 1.84 | 4.05 | 7.03 | 10.72 | 13.85 | 1.75 | 3.77 | 6.42 | 9.36 | 11.42 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 78 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: C27/30/35/40 timber**

| Load duration | Minimum outer member thickness [a] | C27/30/35/40 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 0.92 | 1.32 | 1.68 | 2.00 | 2.28 | 0.83 | 1.15 | 1.40 | 1.61 | 1.77 |
| | 22 | 1.14 | 1.82 | 2.31 | 2.75 | 3.14 | 1.08 | 1.58 | 1.93 | 2.21 | 2.43 |
| | 35 | 1.23 | 2.51 | 3.68 | 4.38 | 4.99 | 1.15 | 2.33 | 3.07 | 3.52 | 3.87 |
| | 44 | 1.34 | 2.59 | 4.34 | 5.51 | 6.28 | 1.25 | 2.38 | 3.86 | 4.43 | 4.87 |
| | 47 | 1.38 | 2.62 | 4.36 | 5.88 | 6.71 | 1.28 | 2.41 | 3.96 | 4.73 | 5.20 |
| | 60 | 1.58 | 2.82 | 4.49 | 6.65 | 8.56 | 1.46 | 2.56 | 4.05 | 5.92 | 6.64 |
| | 72 | 1.60 | 3.04 | 4.69 | 6.78 | 9.31 | 1.52 | 2.74 | 4.18 | 5.99 | 7.97 |
| | 97 | 1.60 | 3.52 | 5.25 | 7.26 | 9.67 | 1.52 | 3.21 | 4.61 | 6.31 | 8.34 |
| | 147 | 1.60 | 3.52 | 6.12 | 8.75 | 11.04 | 1.52 | 3.28 | 5.59 | 7.39 | 9.23 |
| Medium-term | 16 | 1.18 | 1.70 | 2.16 | 2.57 | 2.93 | 1.07 | 1.47 | 1.80 | 2.07 | 2.28 |
| | 22 | 1.29 | 2.34 | 2.97 | 3.54 | 4.04 | 1.21 | 2.03 | 2.48 | 2.85 | 3.13 |
| | 35 | 1.44 | 2.84 | 4.73 | 5.63 | 6.42 | 1.34 | 2.62 | 3.95 | 4.53 | 4.98 |
| | 44 | 1.60 | 2.98 | 4.89 | 7.08 | 8.07 | 1.48 | 2.72 | 4.43 | 5.69 | 6.26 |
| | 47 | 1.66 | 3.03 | 4.93 | 7.36 | 8.62 | 1.53 | 2.77 | 4.45 | 6.08 | 6.69 |
| | 60 | 1.78 | 3.33 | 5.17 | 7.51 | 10.35 | 1.69 | 3.00 | 4.62 | 6.65 | 8.54 |
| | 72 | 1.78 | 3.65 | 5.48 | 7.76 | 10.50 | 1.69 | 3.27 | 4.85 | 6.80 | 9.14 |
| | 97 | 1.78 | 3.92 | 6.30 | 8.52 | 11.14 | 1.69 | 3.65 | 5.48 | 7.33 | 9.51 |
| | 147 | 1.78 | 3.92 | 6.81 | 10.39 | 13.19 | 1.69 | 3.65 | 6.22 | 8.91 | 10.91 |
| Short-term and very short-term | 16 | 1.33 | 1.91 | 2.43 | 2.90 | 3.30 | 1.20 | 1.66 | 2.03 | 2.33 | 2.56 |
| | 22 | 1.37 | 2.63 | 3.35 | 3.98 | 4.54 | 1.30 | 2.28 | 2.79 | 3.20 | 3.52 |
| | 35 | 1.57 | 3.04 | 5.12 | 6.34 | 7.22 | 1.46 | 2.80 | 4.44 | 5.09 | 5.60 |
| | 44 | 1.76 | 3.21 | 5.22 | 7.80 | 9.08 | 1.62 | 2.93 | 4.72 | 6.40 | 7.04 |
| | 47 | 1.82 | 3.28 | 5.27 | 7.83 | 9.70 | 1.68 | 2.98 | 4.75 | 6.84 | 7.52 |
| | 60 | 1.89 | 3.63 | 5.57 | 8.03 | 11.01 | 1.80 | 3.27 | 4.97 | 7.10 | 9.60 |
| | 72 | 1.89 | 4.01 | 5.95 | 8.35 | 11.23 | 1.80 | 3.58 | 5.25 | 7.30 | 9.74 |
| | 97 | 1.89 | 4.16 | 6.91 | 9.27 | 12.02 | 1.80 | 3.87 | 6.00 | 7.95 | 10.22 |
| | 147 | 1.89 | 4.16 | 7.22 | 11.02 | 14.46 | 1.80 | 3.87 | 6.60 | 9.79 | 11.90 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 79 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: D30/35/40 timber**

| Load duration | Minimum outer member thickness [a] | D30/35/40 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 1.32 | 1.89 | 2.41 | 2.87 | 3.27 | 1.55 | 2.32 | 2.80 | 3.17 | 3.44 |
| | 22 | 1.39 | 2.61 | 3.32 | 3.95 | 4.50 | 1.62 | 3.20 | 3.85 | 4.36 | 4.73 |
| | 35 | 1.57 | 3.07 | 5.19 | 6.28 | 7.16 | 1.90 | 3.47 | 5.61 | 6.93 | 7.53 |
| | 44 | 1.76 | 3.23 | 5.28 | 7.89 | 9.00 | 2.16 | 3.70 | 5.75 | 8.32 | 9.46 |
| | 47 | 1.82 | 3.30 | 5.32 | 7.93 | 9.61 | 2.18 | 3.79 | 5.81 | 8.35 | 10.11 |
| | 60 | 1.92 | 3.64 | 5.61 | 8.11 | 11.15 | 2.18 | 4.25 | 6.20 | 8.60 | 11.45 |
| | 72 | 1.92 | 4.01 | 5.98 | 8.41 | 11.35 | 2.18 | 4.67 | 6.65 | 8.96 | 11.68 |
| | 97 | 1.92 | 4.22 | 6.92 | 9.30 | 12.10 | 2.18 | 4.67 | 7.80 | 10.00 | 12.51 |
| | 147 | 1.92 | 4.22 | 7.32 | 11.17 | 14.47 | 2.18 | 4.67 | 7.90 | 11.74 | 15.05 |
| Medium-term | 16 | 1.52 | 2.44 | 3.10 | 3.69 | 4.21 | 1.75 | 2.99 | 3.60 | 4.08 | 4.42 |
| | 22 | 1.59 | 3.33 | 4.26 | 5.07 | 5.79 | 1.87 | 3.70 | 4.95 | 5.60 | 6.08 |
| | 35 | 1.87 | 3.52 | 5.82 | 8.07 | 9.20 | 2.29 | 4.01 | 6.33 | 8.91 | 9.68 |
| | 44 | 2.13 | 3.78 | 6.01 | 8.87 | 11.57 | 2.43 | 4.36 | 6.58 | 9.36 | 12.17 |
| | 47 | 2.13 | 3.88 | 6.09 | 8.92 | 12.36 | 2.43 | 4.49 | 6.69 | 9.43 | 12.68 |
| | 60 | 2.13 | 4.37 | 6.56 | 9.28 | 12.57 | 2.43 | 5.14 | 7.28 | 9.87 | 12.93 |
| | 72 | 2.13 | 4.70 | 7.09 | 9.77 | 12.96 | 2.43 | 5.20 | 7.94 | 10.44 | 13.36 |
| | 97 | 2.13 | 4.70 | 8.16 | 11.09 | 14.16 | 2.43 | 5.20 | 8.79 | 11.97 | 14.67 |
| | 147 | 2.13 | 4.70 | 8.16 | 12.44 | 17.46 | 2.43 | 5.20 | 8.79 | 13.07 | 17.90 |
| Short-term and very short-term | 16 | 1.62 | 2.74 | 3.49 | 4.15 | 4.73 | 1.87 | 3.36 | 4.05 | 4.58 | 4.98 |
| | 22 | 1.71 | 3.53 | 4.80 | 5.71 | 6.51 | 2.02 | 3.94 | 5.57 | 6.30 | 6.84 |
| | 35 | 2.05 | 3.79 | 6.21 | 9.08 | 10.35 | 2.51 | 4.33 | 6.76 | 9.82 | 10.89 |
| | 44 | 2.26 | 4.10 | 6.45 | 9.46 | 13.02 | 2.58 | 4.75 | 7.08 | 9.99 | 13.45 |
| | 47 | 2.26 | 4.22 | 6.56 | 9.53 | 13.14 | 2.58 | 4.91 | 7.22 | 10.08 | 13.49 |
| | 60 | 2.26 | 4.80 | 7.12 | 9.99 | 13.44 | 2.58 | 5.52 | 7.93 | 10.64 | 13.84 |
| | 72 | 2.26 | 4.98 | 7.75 | 10.58 | 13.93 | 2.58 | 5.52 | 8.70 | 11.33 | 14.37 |
| | 97 | 2.26 | 4.98 | 8.65 | 12.14 | 15.39 | 2.58 | 5.52 | 9.33 | 13.12 | 15.95 |
| | 147 | 2.26 | 4.98 | 8.65 | 13.19 | 18.51 | 2.58 | 5.52 | 9.33 | 13.86 | 18.99 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 80 — Basic single shear loads for one 4.6 grade steel bolt or dowel in a three-member timber-to-timber joint: D50/60/70 timber**

| Load duration | Minimum outer member thickness [a] | D50/60/70 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Basic single shear load kN | | | | | | | | | |
| | | Direction of loading | | | | | | | | | |
| | | Parallel to the grain | | | | | Perpendicular to the grain | | | | |
| | | Bolt or dowel diameter (mm) | | | | | Bolt or dowel diameter (mm) | | | | |
| | mm | M8 | M12 | M16 | M20 | M24 | M8 | M12 | M16 | M20 | M24 |
| Long-term | 16 | 1.51 | 2.33 | 2.96 | 3.52 | 4.02 | 1.73 | 2.85 | 3.44 | 3.89 | 4.22 |
| | 22 | 1.57 | 3.20 | 4.07 | 4.85 | 5.52 | 1.84 | 3.67 | 4.73 | 5.35 | 5.80 |
| | 35 | 1.83 | 3.47 | 5.78 | 7.71 | 8.79 | 2.22 | 3.94 | 6.26 | 8.50 | 9.23 |
| | 44 | 2.07 | 3.70 | 5.93 | 8.80 | 11.05 | 2.42 | 4.26 | 6.49 | 9.27 | 11.61 |
| | 47 | 2.12 | 3.79 | 6.01 | 8.84 | 11.80 | 2.42 | 4.38 | 6.58 | 9.33 | 12.40 |
| | 60 | 2.12 | 4.25 | 6.43 | 9.15 | 12.45 | 2.42 | 4.99 | 7.12 | 9.72 | 12.80 |
| | 72 | 2.12 | 4.67 | 6.92 | 9.59 | 12.78 | 2.42 | 5.17 | 7.73 | 10.23 | 13.17 |
| | 97 | 2.12 | 4.67 | 8.12 | 10.81 | 13.88 | 2.42 | 5.17 | 8.75 | 11.64 | 14.35 |
| | 147 | 2.12 | 4.67 | 8.12 | 12.37 | 17.02 | 2.42 | 5.17 | 8.75 | 13.00 | 17.72 |
| Medium-term | 16 | 1.70 | 2.99 | 3.81 | 4.53 | 5.16 | 1.97 | 3.67 | 4.42 | 5.00 | 5.43 |
| | 22 | 1.80 | 3.70 | 5.23 | 6.23 | 7.10 | 2.14 | 4.13 | 6.08 | 6.87 | 7.46 |
| | 35 | 2.19 | 4.01 | 6.52 | 9.76 | 11.30 | 2.69 | 4.59 | 7.11 | 10.27 | 11.87 |
| | 44 | 2.36 | 4.36 | 6.81 | 9.92 | 13.71 | 2.69 | 5.07 | 7.49 | 10.49 | 14.07 |
| | 47 | 2.36 | 4.50 | 6.93 | 10.01 | 13.75 | 2.69 | 5.24 | 7.64 | 10.60 | 14.12 |
| | 60 | 2.36 | 5.14 | 7.57 | 10.56 | 14.14 | 2.69 | 5.76 | 8.45 | 11.25 | 14.55 |
| | 72 | 2.36 | 5.20 | 8.29 | 11.24 | 14.71 | 2.69 | 5.76 | 9.32 | 12.04 | 15.18 |
| | 97 | 2.36 | 5.20 | 9.04 | 13.00 | 16.39 | 2.69 | 5.76 | 9.74 | 14.06 | 16.99 |
| | 147 | 2.36 | 5.20 | 9.04 | 13.78 | 19.34 | 2.69 | 5.76 | 9.74 | 14.47 | 19.82 |
| Short-term and very short-term | 16 | 1.81 | 3.36 | 4.28 | 5.10 | 5.81 | 2.11 | 4.12 | 4.97 | 5.62 | 6.10 |
| | 22 | 1.95 | 3.94 | 5.89 | 7.01 | 7.99 | 2.32 | 4.41 | 6.84 | 7.73 | 8.39 |
| | 35 | 2.40 | 4.33 | 6.98 | 10.38 | 12.71 | 2.86 | 4.98 | 7.62 | 10.93 | 13.35 |
| | 44 | 2.51 | 4.75 | 7.34 | 10.61 | 14.58 | 2.86 | 5.54 | 8.09 | 11.23 | 14.97 |
| | 47 | 2.51 | 4.91 | 7.48 | 10.73 | 14.65 | 2.86 | 5.75 | 8.28 | 11.37 | 15.05 |
| | 60 | 2.51 | 5.52 | 8.25 | 11.40 | 15.16 | 2.86 | 6.11 | 9.23 | 12.17 | 15.62 |
| | 72 | 2.51 | 5.52 | 9.09 | 12.21 | 15.87 | 2.86 | 6.11 | 10.24 | 13.11 | 16.40 |
| | 97 | 2.51 | 5.52 | 9.58 | 14.28 | 17.87 | 2.86 | 6.11 | 10.33 | 15.35 | 18.54 |
| | 147 | 2.51 | 5.52 | 9.58 | 14.61 | 20.51 | 2.86 | 6.11 | 10.33 | 15.35 | 21.03 |

[a] The corresponding minimum inner member thickness is assumed to be double the tabulated value.

**Table 81 — Minimum bolt spacings**

| Direction of loading | End distance | | Edge distance | | Distances between bolts or rows of bolts | |
|---|---|---|---|---|---|---|
| | Loaded | Unloaded | Loaded | Unloaded | Measured across the grain | Measured parallel to the grain |
| Loading parallel to grain | $7d$ | $4d$ | $1.5d$ | $1.5d$ | $4d$ | $4d$ |
| Loading perpendicular to grain | $4d$ | $4d$ | $4d$ | $1.5d$ | $4d$ | $4d$ |

## 6.7 Toothed-plate connector joints

### 6.7.1 General

**6.7.1.1** ***Connector sizes***

The recommendations contained in **6.7** are applicable to the sizes of toothed-plate connectors given in Table 82 and conforming to BS 1579.

**6.7.1.2** ***Bolts and washers***

The diameters of the bolts to be used with the connectors are given in Table 82. Bolt holes should be as close as practicable to the nominal diameter of the bolt, and in no case more than 2.0 mm larger than the bolt diameter.

Round or square washers should be fitted between the timber and the head and nut of the bolt. The minimum size of washer to be used with each connector is given in Table 82.

Connectors should not bear on the threads of bolts.

**6.7.1.3** ***Joint preparation***

To prepare a connectored joint, the positions of the bolt holes should be accurately set out with reference to the point of intersection of the centre-lines of the members. One of the following two procedures should be used when drilling the bolt holes:

a) fit the members together in their correct positions and clamp while drilling the bolt holes through all the members;

b) drill the bolt holes in the individual members using jigs or templates to locate the bolt holes accurately.

Bolt holes should be within 2 mm of their specified position.

### 6.7.2 Effective cross-section

When assessing the effective cross-section of multiple connector joints, all connectors and their bolts that lie within a distance of 0.75 times the nominal size of the connector measured parallel to the grain from a given cross-section should be considered as occurring at that cross-section. The effective cross-section should then be determined by deducting the net projected area of the bolt holes from the gross area of the cross-section.

### 6.7.3 Connector spacing

**6.7.3.1** ***Spacing***

Associated with each type and size of toothed-plate connector is a standard end distance, edge distance and spacing between connectors which permit the basic load to be used. These standard distances are given in Table 83, Table 84 and Table 85. If the end distance, edge distance or spacing is less than the standard, then the basic load should be modified (see **6.7.6**).

**6.7.3.2** ***End distance***

When the end of a member is cut at right angles to its length, the end distance is the distance, measured along the length, from the end of the member to the centre of the connector. If the end of a member is not cut square (see Figure 7), the end distance is the shortest distance, measured along the length, from the end of the member to any point on the centre half of:

a) the diameter, perpendicular to the grain, for a round connector;

b) the width, at the centre and perpendicular to the grain, for a square connector.

An end distance is said to be loaded when the force from the connector has a component acting towards that end of the member.

**6.7.3.3** ***Edge distance***

The edge distance is the distance from the edge of the member to the centre of the connector, measured perpendicular to the edge.

If the end of the member is not cut square, then the perpendicular distance from the centre of the connector to the sloping end cut should be not less than the edge distance.

The edge distance is said to be loaded when the force from the connector has a component acting towards that edge of the member.

**Table 82 — Sizes of toothed-plate connectors and minimum sizes of washers**

| Connector | | Bolt | Minimum size of round or square washers | |
|---|---|---|---|---|
| Type | Nominal size<br>mm | Nominal size and thread diameter | Diameter or length of side<br>mm | Thickness<br>mm |
| Round toothed-plate, double- and single-sided | 38 | M10 | 38 | 3 |
| | 51 | M12 | 38 | 3 |
| | 64 | M12 | 50 | 5 |
| | 76 | M12 | 60 | 5 |
| Square toothed-plate, double- and single-sided | 38 | M10 | 38 | 3 |
| | 51 | M12 | 50 | 3 |
| | 64 | M12 | 60 | 5 |
| | 76 | M12 | 75 | 5 |
| NOTE The connector sizes in this table are metric conversions of the imperial sizes given in BS 1579. | | | | |

**Table 83 — End distances for toothed-plate connectors**

| Type of connector | Angle of load to grain [a] $\alpha$ | Connector size mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 38 | | 51 | | 64 | | 76 | |
| | degrees | Minimum | Standard | Minimum | Standard | Minimum | Standard | Minimum | Standard |
| Round toothed-plate: | | | | | | | | | |
| — unloaded end distance | 0 | 32 | 32 | 38 | 38 | 44 | 44 | 51 | 51 |
| | 45 | 32 | 57 | 38 | 63 | 44 | 70 | 51 | 76 |
| | 90 | 32 | 83 | 38 | 89 | 44 | 95 | 51 | 102 |
| — loaded end distance | 0 to 90 | 32 | 83 | 38 | 89 | 44 | 95 | 51 | 102 |
| Square toothed-plate: | | | | | | | | | |
| — unloaded end distance | 0 | 35 | 35 | 41 | 41 | 48 | 48 | 54 | 54 |
| | 45 | 35 | 60 | 41 | 66 | 48 | 73 | 54 | 80 |
| | 90 | 35 | 86 | 41 | 92 | 48 | 98 | 54 | 105 |
| — loaded end distance | 0 to 90 | 35 | 86 | 41 | 92 | 48 | 98 | 54 | 105 |

[a] For intermediate angles, values should be obtained by linear interpolation.

**Table 84 — Edge distances for toothed-plate connectors**

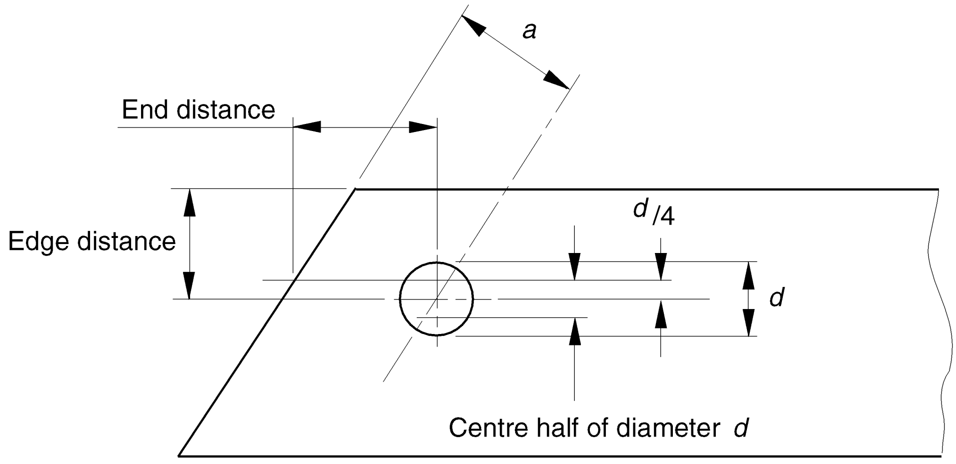
| Type of connector | Angle of load to grain $a$<br>degrees | Connector size mm | | | |
|---|---|---|---|---|---|
| | | 38 | 51 | 64 | 76 |
| | | Minimum and standard | Minimum and standard | Minimum and standard | Minimum and standard |
| Round toothed-plate:<br>— unloaded and loaded edge distance | 0 to 90 | 25 | 32 | 38 | 44 |
| Square toothed-plate:<br>— unloaded and loaded edge distance | 0 to 90 | 29 | 35 | 41 | 48 |

**Table 85 — Spacing modification factor, $K_s$, for toothed-plate connectors**

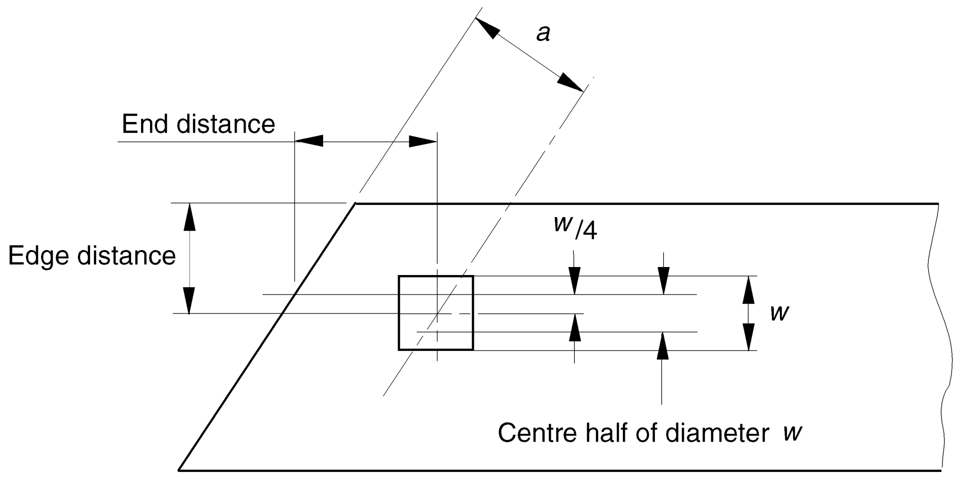
| Angle of load to grain $\alpha$ | Angle of connector axis to grain $\theta$ | Spacing mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Connector side length mm | | | | | | | |
| | | 38 | | 51 | | 64 | | 76 | |
| degrees | degrees | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) |
| **Round toothed-plate** | | | | | | | | | |
| 0 | 0 | 51 | 57 | 64 | 76 | 76 | 95 | 89 | 114 |
| | 45 | 51 | 54 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 90 | 51 | 51 | 64 | 64 | 76 | 76 | 89 | 89 |
| 15 | 0 | 51 | 57 | 64 | 73 | 76 | 92 | 89 | 108 |
| | 45 | 51 | 57 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 90 | 51 | 54 | 64 | 67 | 76 | 83 | 89 | 95 |
| 30 | 0 | 51 | 54 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 45 | 51 | 54 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 90 | 51 | 54 | 64 | 70 | 76 | 86 | 89 | 102 |
| 45 | 0 | 51 | 54 | 64 | 67 | 76 | 83 | 89 | 95 |
| | 45 | 51 | 57 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 90 | 51 | 57 | 64 | 73 | 76 | 92 | 89 | 108 |
| 60 to 90 | 0 | 51 | 51 | 64 | 64 | 76 | 76 | 89 | 89 |
| | 45 | 51 | 54 | 64 | 70 | 76 | 86 | 89 | 102 |
| | 90 | 51 | 57 | 64 | 76 | 76 | 95 | 89 | 114 |

**Table 85 — Spacing modification factor, $K_s$, for toothed-plate connectors** (*continued*)

| Angle of load to grain $\alpha$ degrees | Angle of connector axis to grain $\theta$ degrees | Spacing mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Connector side length mm | | | | | | | |
| | | 38 | | 51 | | 64 | | 76 | |
| | | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) | Minimum ($K_s$ = 0.75) | Standard ($K_s$ = 1.00) |
| **Square toothed-plate** | | | | | | | | | |
| 0 | 0 | 57 | 67 | 70 | 86 | 83 | 105 | 95 | 124 |
| | 45 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 90 | 57 | 57 | 70 | 70 | 83 | 83 | 95 | 95 |
| 15 | 0 | 57 | 67 | 70 | 83 | 83 | 102 | 95 | 117 |
| | 45 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 90 | 57 | 60 | 70 | 76 | 83 | 89 | 95 | 102 |
| 30 | 0 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 45 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 90 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| 45 | 0 | 57 | 60 | 70 | 76 | 83 | 89 | 95 | 102 |
| | 45 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 90 | 57 | 67 | 70 | 83 | 83 | 102 | 95 | 117 |
| 60 to 90 | 0 | 57 | 57 | 70 | 70 | 83 | 83 | 95 | 95 |
| | 45 | 57 | 64 | 70 | 79 | 83 | 95 | 95 | 111 |
| | 90 | 57 | 67 | 70 | 86 | 83 | 105 | 95 | 124 |




a) Round connector




b) Square connector

NOTE *a* should be not less than the appropriate edge distance.

**Figure 7 — Connector end and edge distances**

### 6.7.4 Timber-to-timber joints

#### 6.7.4.1 *Assembly*

Toothed-plate connectors should be embedded prior to the insertion of the bolt by using a high-tensile steel screwed rod, with plate washers larger than the connectors between the timber surfaces and the nuts at the two ends of the screwed rod. For large connectors or multi-member joints, thrust bearings may have to be used under the nuts. The screwed rod should be tightened sufficiently to embed fully the connector teeth, and the washers used should be of sufficient size to avoid undue crushing of the timber.

The joint should be clamped before the screwed rod is withdrawn and the permanent bolt, with the appropriate washers, is inserted. Alternatively, a press may be used but care should be taken to ensure positive location of the connectors between the member surfaces.

Toothed-plate connectors may be used generally with all softwood species, and with those hardwoods which conform to strength classes D30 to D40, provided full embedment of the teeth can be achieved. They are not suitable for use with denser hardwood species of the D50 to D70 classes.

#### 6.7.4.2 *Connector unit*

A connector unit consists of one double-sided toothed-plate connector, or two single-sided toothed-plate connectors back to back, with the bolt in single shear in a timber-to-timber joint.

#### 6.7.4.3 *Basic loads*

The basic loads parallel and perpendicular to the grain for toothed-plate connector units are given in Table 86 for timber members satisfying the requirements for strength classes C14 to C40 and TR26. The values apply to hardwood species included in classes D30 to D40 only if the teeth of the connectors can be fully embedded (see **6.7.4.1**).

Where the load is inclined at an angle, $\alpha$, to the grain of the timber, the basic load, $F$, should be determined from the equation given in **6.6.4.1**.

The basic loads given in this clause for each toothed-plate connector unit should be modified in accordance with **6.7.6** to determine the permissible load for a joint.

### 6.7.5 Steel plate-to-timber joints

#### 6.7.5.1 *Connector unit*

A connector unit consists of one single-sided toothed-plate connector with its bolt in single shear in a steel plate-to-timber joint.

#### 6.7.5.2 *Steel plates*

Steel plates should have adequate strength and be designed in accordance with BS 449-2.

#### 6.7.5.3 *Basic loads*

The basic loads for each single-sided toothed-plate connector unit in a steel plate-to-timber joint should be obtained in accordance with **6.7.4.3** and modified in accordance with **6.7.6** to determine the permissible load for the joint.

### 6.7.6 Permissible load for a joint

Where more than one connector is used with the same bolt in a multi-member joint, the appropriate permissible load should be calculated for each connector unit, and these loads should be added together.

The permissible load for a toothed-plate connectored joint, $F_{adm}$, should be determined as the sum of the permissible loads for each connector unit in the joints where each permissible connector unit load should be calculated as:

$$F_{adm} = F \times K_{58} \times K_{59} \times K_{60} \times K_{61}$$

where the basic load for a single toothed-plate connector unit, $F$, is taken from **6.7.4.3** or **6.7.5.3**, as appropriate, and

$K_{58}$ is the modification factor for duration of loading;

$K_{59}$ is the modification factor for moisture content;

$K_{60}$ is the modification factor for end distance, edge distance and spacing;

$K_{61}$ is the modification factor for the number of connectors in each line.

For duration of loading:

$K_{58}$ = 1.00 for long-term loads;

$K_{58}$ = 1.12 for medium-term loads;

$K_{58}$ = 1.25 for short- and very short-term loads.

For moisture content:

$K_{59}$ = 1.00 for a joint in service class 1 or 2;

$K_{59}$ = 0.7 for a joint in service class 3.

For end distance, edge distance and spacing:

if the standard end distances, edge distances and spacings given in Table 83, Table 84 and Table 85 are used:

$$K_{60} = 1.0$$

If the end distance and/or centre spacing of the connectors are less than the relevant standard values given in Table 83 and Table 85, respectively, the modification factor, $K_{60}$, should have the lower of the values for $K_c$ and $K_s$ given in Table 87 and Table 88, and Table 85, respectively. In no case should the end distance and spacing be less than the minimum values given in Table 83 and Table 85. For intermediate values, the factors $K_c$ and $K_s$ may be obtained by linear interpolation. No increase in load is permitted if end distance, edge distance or centre spacing exceeds the standard values. Note that the standard value of edge distance given in Table 84 is also the minimum value that can be used.

For the number of connector units in each line:

where a number of connector units of the same size are symmetrically arranged in one or more lines parallel to the line of action of the load in a primary axially loaded member in a structural framework (see **1.6.11**) then:

$$K_{61} = 1 - \frac{3(n-1)}{100} \text{ for } n < 10$$

$$K_{61} = 0.7 \text{ for } n \geq 10$$

where $n$ is the number of connector units in each line.

In all other loading cases where more than one toothed-plate connector unit is used in a joint:

$$K_{61} = 1.0$$

**Table 86 — Basic loads for one toothed-plate connector unit**

| Actual nominal size of connector | Nominal bolt size and thread diameter | Thickness of members [a] | | Basic load for one toothed-plate connector in timber of strength class: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connector on one side only | Connectors on both sides and on same bolt | C14 | | C16/18/22 | | C24 | | C27/30/35/40 | |
| | | | | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain |
| mm | mm | mm | mm | kN | | | | | | | |
| 38 round or square | M10 | 16 | 32 | 1.71 | 1.24 | 1.80 | 1.29 | 2.08 | 1.45 | 2.27 | 1.54 |
| | | 19 | 38 | 1.87 | 1.32 | 1.97 | 1.38 | 2.28 | 1.54 | 2.50 | 1.65 |
| | | 22 | 44 | 2.02 | 1.40 | 2.12 | 1.46 | 2.44 | 1.64 | 2.66 | 1.75 |
| | | 25 and over | 50 and over | 2.15 | 1.48 | 2.25 | 1.54 | 2.55 | 1.74 | 2.78 | 1.86 |
| 51 round | M12 | 16 | 32 | 2.28 | 1.67 | 2.40 | 1.74 | 2.77 | 1.95 | 3.02 | 2.08 |
| | | 19 | 38 | 2.48 | 1.76 | 2.62 | 1.83 | 3.02 | 2.06 | 3.31 | 2.19 |
| | | 22 | 44 | 2.67 | 1.85 | 2.82 | 1.93 | 3.26 | 2.16 | 3.58 | 2.31 |
| | | 25 | 50 | 2.86 | 1.93 | 3.01 | 2.01 | 3.48 | 2.27 | 3.81 | 2.42 |
| | | 29 | — | 3.07 | 2.05 | 3.22 | 2.14 | 3.67 | 2.41 | 4.01 | 2.58 |
| | | — | 60 | 3.12 | 2.08 | 3.27 | 2.17 | 3.71 | 2.45 | 4.06 | 2.62 |
| | | — | 63 | 3.16 | 2.12 | 3.31 | 2.21 | 3.74 | 2.50 | 4.09 | 2.67 |
| | | 36 | 72 | 3.27 | 2.25 | 3.40 | 2.35 | 3.80 | 2.66 | 4.13 | 2.85 |
| | | 50 and over | 100 and over | 3.27 | 2.55 | 3.40 | 2.67 | 3.81 | 3.03 | 4.14 | 3.22 |
| 51 square | M12 | 16 | 32 | 2.55 | 1.94 | 2.68 | 2.02 | 3.07 | 2.24 | 3.34 | 2.39 |
| | | 19 | 38 | 2.75 | 2.03 | 2.89 | 2.11 | 3.33 | 2.36 | 3.63 | 2.51 |
| | | 22 | 44 | 2.95 | 2.12 | 3.10 | 2.21 | 3.57 | 2.46 | 3.89 | 2.62 |
| | | 25 | 50 | 3.13 | 2.20 | 3.29 | 2.29 | 3.78 | 2.57 | 4.13 | 2.74 |
| | | 29 | — | 3.34 | 2.32 | 3.50 | 2.42 | 3.97 | 2.71 | 4.33 | 2.90 |
| | | — | 60 | 3.39 | 2.35 | 3.55 | 2.45 | 4.01 | 2.74 | 4.37 | 2.93 |
| | | — | 63 | 3.43 | 2.39 | 3.58 | 2.49 | 4.05 | 2.80 | 4.40 | 2.99 |
| | | 36 | 72 | 3.54 | 2.52 | 3.68 | 2.63 | 4.10 | 2.96 | 4.45 | 3.17 |
| | | 50 and over | 100 and over | 3.54 | 2.82 | 3.68 | 2.95 | 4.11 | 3.32 | 4.46 | 3.53 |

[a] For intermediate thicknesses, values may be obtained by linear interpolation.

**Table 86 — Basic loads for one toothed-plate connector unit** (*continued*)

| Actual nominal size of connector | Nominal bolt size and thread diameter | Thickness of members [a] | | Basic load for one toothed-plate connector in timber of strength class: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connector on one side only | Connectors on both sides and on same bolt | C14 | | C16/18/22 | | C24 | | C27/30/35/40 | |
| | | | | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain |
| mm | mm | mm | mm | kN | | | | | | | |
| 64 round or square | M12 | 16 | 32 | 2.90 | 2.29 | 3.05 | 2.39 | 3.50 | 2.67 | 3.81 | 2.86 |
| | | 19 | 38 | 3.10 | 2.38 | 3.26 | 2.48 | 3.76 | 2.78 | 4.10 | 2.97 |
| | | 22 | 44 | 3.29 | 2.47 | 3.47 | 2.58 | 3.99 | 2.89 | 4.36 | 3.10 |
| | | 25 | 50 | 3.48 | 2.55 | 3.66 | 2.66 | 4.21 | 3.00 | 4.60 | 3.21 |
| | | 29 | — | 3.69 | 2.67 | 3.87 | 2.79 | 4.40 | 3.14 | 4.80 | 3.37 |
| | | — | 60 | 3.74 | 2.70 | 3.92 | 2.82 | 4.44 | 3.17 | 4.84 | 3.40 |
| | | — | 63 | 3.78 | 2.74 | 3.95 | 2.86 | 4.48 | 3.23 | 4.87 | 3.46 |
| | | 36 | 72 | 3.89 | 2.87 | 4.05 | 3.00 | 4.53 | 3.39 | 4.92 | 3.64 |
| | | 50 and over | 100 and over | 3.89 | 3.17 | 4.05 | 3.32 | 4.54 | 3.75 | 4.93 | 4.00 |
| 76 round | M12 | 16 | 32 | 3.34 | 2.74 | 3.52 | 2.86 | 4.04 | 3.22 | 4.41 | 3.45 |
| | | 19 | 38 | 3.54 | 2.82 | 3.73 | 2.95 | 4.30 | 3.32 | 4.69 | 3.57 |
| | | 22 | 44 | 3.74 | 2.91 | 3.94 | 3.04 | 4.54 | 3.44 | 4.96 | 3.69 |
| | | 25 | 50 | 3.92 | 2.99 | 4.13 | 3.13 | 4.74 | 3.54 | 5.18 | 3.81 |
| | | 29 | — | 4.13 | 3.11 | 4.33 | 3.25 | 4.95 | 3.69 | 5.40 | 3.96 |
| | | — | 60 | 4.18 | 3.14 | 4.38 | 3.28 | 4.99 | 3.72 | 5.44 | 4.00 |
| | | — | 63 | 4.23 | 3.18 | 4.43 | 3.33 | 5.02 | 3.77 | 5.47 | 4.06 |
| | | 36 | 72 | 4.33 | 3.31 | 4.52 | 3.47 | 5.07 | 3.93 | 5.51 | 4.23 |
| | | 50 and over | 100 and over | 4.34 | 3.61 | 4.53 | 3.78 | 5.08 | 4.30 | 5.52 | 4.59 |

[a] For intermediate thicknesses, values may be obtained by linear interpolation.

**Table 86 — Basic loads for one toothed-plate connector unit** (*continued*)

| Actual nominal size of connector | Nominal bolt size and thread diameter | Thickness of members [a] | | Basic load for one toothed-plate connector in timber of strength class: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connector on one side only | Connectors on both sides and on same bolt | C14 | | C16/18/22 | | C24 | | C27/30/35/40 | |
| | | | | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain | Parallel to grain | Perpendicular to grain |
| mm | mm | mm | mm | kN | | | | | | | |
| 76 square | M12 | 16 | 32 | 3.76 | 3.15 | 3.96 | 3.30 | 4.56 | 3.73 | 4.97 | 4.02 |
| | | 19 | 38 | 3.96 | 3.24 | 4.17 | 3.39 | 4.81 | 3.84 | 5.25 | 4.13 |
| | | 22 | 44 | 4.15 | 3.33 | 4.37 | 3.48 | 5.05 | 3.95 | 5.52 | 4.25 |
| | | 25 | 50 | 4.34 | 3.41 | 4.57 | 3.57 | 5.26 | 4.05 | 5.75 | 4.36 |
| | | 29 | — | 4.55 | 3.53 | 4.78 | 3.70 | 5.45 | 4.19 | 5.95 | 4.52 |
| | | — | 60 | 4.60 | 3.55 | 4.82 | 3.72 | 5.50 | 4.23 | 5.99 | 4.56 |
| | | — | 63 | 4.64 | 3.60 | 4.86 | 3.77 | 5.53 | 4.28 | 6.03 | 4.61 |
| | | 36 | 72 | 4.75 | 3.73 | 4.96 | 3.91 | 5.58 | 4.44 | 6.07 | 4.79 |
| | | 50 and over | 100 and over | 4.75 | 4.02 | 4.96 | 4.22 | 5.59 | 4.81 | 6.08 | 5.16 |

[a] For intermediate thicknesses, values may be obtained by linear interpolation.

**Table 87 — Unloaded end distance modification factor, $K_c$, for toothed-plate connectors**

| Unloaded end distance | Value of $K_c$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Connector size | | | | | | | | | | | |
| | 38 mm | | | 51 mm | | | 64 mm | | | 76 mm | | |
| | Angle [a] of load to grain $\alpha$ | | | | | | | | | | | |
| | 0° | 45° | 90° | 0° | 45° | 90° | 0° | 45° | 90° | 0° | 45° | 90° |
| **Round toothed-plate** | | | | | | | | | | | | |
| 35 | 1.00 | 0.89 | 0.76 | | | | | | | | | |
| 40 | 1.00 | 0.91 | 0.79 | 1.00 | 0.88 | 0.76 | | | | | | |
| 45 | 1.00 | 0.94 | 0.81 | 1.00 | 0.91 | 0.78 | 1.00 | 0.90 | 0.80 | | | |
| 50 | 1.00 | 0.96 | 0.84 | 1.00 | 0.93 | 0.81 | 1.00 | 0.92 | 0.82 | | | |
| 55 | 1.00 | 0.99 | 0.86 | 1.00 | 0.96 | 0.83 | 1.00 | 0.94 | 0.84 | 1.00 | 0.92 | 0.83 |
| 60 | 1.00 | 1.00 | 0.89 | 1.00 | 0.98 | 0.86 | 1.00 | 0.96 | 0.86 | 1.00 | 0.94 | 0.85 |
| 65 | 1.00 | 1.00 | 0.91 | 1.00 | 1.00 | 0.88 | 1.00 | 0.98 | 0.88 | 1.00 | 0.96 | 0.87 |
| 70 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 0.91 | 1.00 | 1.00 | 0.90 | 1.00 | 0.98 | 0.89 |
| 75 | 1.00 | 1.00 | 0.96 | 1.00 | 1.00 | 0.93 | 1.00 | 1.00 | 0.92 | 1.00 | 0.99 | 0.90 |
| 80 | 1.00 | 1.00 | 0.99 | 1.00 | 1.00 | 0.96 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 0.92 |
| 85 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 1.00 | 1.00 | 0.96 | 1.00 | 1.00 | 0.94 |
| 90 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 1.00 | 1.00 | 0.96 |
| 95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 |
| 100 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 105 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Square toothed-plate** | | | | | | | | | | | | |
| 35 | 1.00 | 0.90 | 0.80 | | | | | | | | | |
| 40 | 1.00 | 0.92 | 0.82 | | | | | | | | | |
| 45 | 1.00 | 0.94 | 0.84 | 1.00 | 0.92 | 0.82 | | | | | | |
| 50 | 1.00 | 0.96 | 0.86 | 1.00 | 0.94 | 0.84 | 1.00 | 0.92 | 0.83 | | | |
| 55 | 1.00 | 0.98 | 0.88 | 1.00 | 0.95 | 0.85 | 1.00 | 0.94 | 0.85 | 1.00 | 0.93 | 0.85 |
| 60 | 1.00 | 1.00 | 0.90 | 1.00 | 0.97 | 0.87 | 1.00 | 0.95 | 0.86 | 1.00 | 0.94 | 0.87 |
| 65 | 1.00 | 1.00 | 0.92 | 1.00 | 0.99 | 0.89 | 1.00 | 0.97 | 0.88 | 1.00 | 0.96 | 0.88 |
| 70 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 0.91 | 1.00 | 0.99 | 0.90 | 1.00 | 0.97 | 0.90 |
| 75 | 1.00 | 1.00 | 0.96 | 1.00 | 1.00 | 0.93 | 1.00 | 1.00 | 0.92 | 1.00 | 0.99 | 0.91 |
| 80 | 1.00 | 1.00 | 0.98 | 1.00 | 1.00 | 0.95 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 0.93 |
| 85 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 1.00 | 1.00 | 0.95 | 1.00 | 1.00 | 0.94 |
| 90 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 1.00 | 1.00 | 0.97 | 1.00 | 1.00 | 0.96 |
| 95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 1.00 | 1.00 | 0.97 |
| 100 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 |
| 105 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

[a] For intermediate angles and end distances, values may be obtained by linear interpolation.

**Table 88 — Loaded end distance modification factor, $K_c$, for toothed-plate connectors**

| Loaded end distance | Value of $K_c$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Connector size | | | | | | | | | | | |
| | 38 mm | | | 51 mm | | | 64 mm | | | 76 mm | | |
| | Angle [a] of load to grain $\alpha$ | | | | | | | | | | | |
| | 0° | 45° | 90° | 0° | 45° | 90° | 0° | 45° | 90° | 0° | 45° | 90° |
| **Round toothed-plate** | | | | | | | | | | | | |
| 35 | 0.53 | 0.65 | 0.76 | | | | | | | | | |
| 40 | 0.58 | 0.68 | 0.79 | 0.52 | 0.64 | 0.76 | | | | | | |
| 45 | 0.63 | 0.72 | 0.81 | 0.57 | 0.68 | 0.78 | 0.61 | 0.71 | 0.80 | | | |
| 50 | 0.68 | 0.76 | 0.84 | 0.62 | 0.71 | 0.81 | 0.65 | 0.74 | 0.82 | | | |
| 55 | 0.73 | 0.79 | 0.86 | 0.67 | 0.75 | 0.83 | 0.69 | 0.76 | 0.84 | 0.68 | 0.76 | 0.83 |
| 60 | 0.77 | 0.83 | 0.89 | 0.72 | 0.79 | 0.86 | 0.73 | 0.79 | 0.86 | 0.71 | 0.78 | 0.85 |
| 65 | 0.82 | 0.87 | 0.91 | 0.76 | 0.82 | 0.88 | 0.76 | 0.82 | 0.88 | 0.75 | 0.81 | 0.87 |
| 70 | 0.87 | 0.90 | 0.94 | 0.81 | 0.86 | 0.91 | 0.80 | 0.85 | 0.90 | 0.78 | 0.83 | 0.89 |
| 75 | 0.92 | 0.94 | 0.96 | 0.86 | 0.90 | 0.93 | 0.84 | 0.88 | 0.92 | 0.81 | 0.86 | 0.90 |
| 80 | 0.97 | 0.98 | 0.99 | 0.91 | 0.93 | 0.96 | 0.88 | 0.91 | 0.94 | 0.85 | 0.89 | 0.92 |
| 85 | 1.00 | 1.00 | 1.00 | 0.96 | 0.97 | 0.98 | 0.92 | 0.94 | 0.96 | 0.88 | 0.91 | 0.94 |
| 90 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.96 | 0.97 | 0.98 | 0.92 | 0.94 | 0.96 |
| 95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.96 | 0.98 |
| 100 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 |
| 105 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Square toothed-plate** | | | | | | | | | | | | |
| 35 | 0.60 | 0.70 | 0.80 | | | | | | | | | |
| 40 | 0.64 | 0.73 | 0.82 | | | | | | | | | |
| 45 | 0.68 | 0.76 | 0.84 | 0.63 | 0.72 | 0.82 | | | | | | |
| 50 | 0.72 | 0.79 | 0.86 | 0.67 | 0.75 | 0.84 | 0.66 | 0.75 | 0.83 | | | |
| 55 | 0.76 | 0.82 | 0.88 | 0.71 | 0.78 | 0.85 | 0.70 | 0.77 | 0.85 | 0.71 | 0.78 | 0.85 |
| 60 | 0.80 | 0.85 | 0.90 | 0.75 | 0.81 | 0.87 | 0.73 | 0.80 | 0.86 | 0.74 | 0.80 | 0.87 |
| 65 | 0.84 | 0.88 | 0.92 | 0.79 | 0.84 | 0.89 | 0.77 | 0.83 | 0.88 | 0.76 | 0.82 | 0.88 |
| 70 | 0.87 | 0.91 | 0.94 | 0.83 | 0.87 | 0.91 | 0.80 | 0.85 | 0.90 | 0.79 | 0.85 | 0.90 |
| 75 | 0.91 | 0.94 | 0.96 | 0.87 | 0.90 | 0.93 | 0.84 | 0.88 | 0.92 | 0.82 | 0.87 | 0.91 |
| 80 | 0.95 | 0.96 | 0.98 | 0.91 | 0.93 | 0.95 | 0.87 | 0.90 | 0.94 | 0.85 | 0.89 | 0.93 |
| 85 | 0.99 | 0.99 | 1.00 | 0.95 | 0.96 | 0.97 | 0.91 | 0.93 | 0.95 | 0.88 | 0.91 | 0.94 |
| 90 | 1.00 | 1.00 | 1.00 | 0.98 | 0.99 | 0.99 | 0.94 | 0.96 | 0.97 | 0.91 | 0.93 | 0.96 |
| 95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 0.98 | 0.99 | 0.94 | 0.96 | 0.97 |
| 100 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 0.98 | 0.99 |
| 105 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

[a] For intermediate angles and end distances, values may be obtained by linear interpolation.

## 6.8 Split-ring connector joints

### 6.8.1 General

#### 6.8.1.1 *Connector sizes*

The recommendations contained in **6.8** are applicable to the sizes of split-ring connectors given in Table 89 and conforming to BS 1579.

**Table 89 — Sizes of split-ring connectors and minimum sizes of washers**

| Nominal size of connector | Nominal size and thread diameter of bolt | Minimum size of round or square washers | |
|---|---|---|---|
| | | Diameter or length of side | Thickness |
| mm | | mm | mm |
| 64 | M12 | 50 | 3 |
| 102 | M20 | 75 | 5 |
| NOTE The sizes in this table are metric conversions of the imperial sizes given in BS 1579. | | | |

#### 6.8.1.2 *Bolts and washers*

The diameters of the bolts to be used with the connectors are given in Table 89. Bolt holes should be as close as practicable to the nominal diameter of the bolt, and in no case more than 2.0 mm larger than the bolt diameter.

Round or square washers should be fitted between the timber and the head and nut of the bolt. The minimum size of washer to be used with each connector is given in Table 89.

#### 6.8.1.3 *Joint preparation*

To prepare a connectored joint, the positions of the bolt holes should be set out accurately with reference to the point of intersection of the centre-lines of the members. One of the following two procedures should be used when drilling the bolt holes:

a) fit the members together in their correct positions and clamp while drilling the bolt holes through all the members;

b) drill the bolt holes in the individual members using jigs or templates to locate the bolt holes accurately.

Bolt holes should be within 2 mm of their specified position.

The contact surfaces of the timber members should be grooved to the dimensions given in Table 90.

The grooves for split-rings may be cut simultaneously with the drilling of the bolt holes if procedure b) is used.

### 6.8.2 Effective cross-section

The effective cross-section of each member at a joint should be determined by deducting from the gross area of the cross-section, the projected area of the connector groove or grooves (i.e. 705 mm$^2$ for each 64 mm split-ring, or 1 455 mm$^2$ for each 102 mm split-ring) and the projected area of the portion of the bolt hole not within the projected area of the groove. The depths of the connector grooves are given in Table 90.

**Table 90 — Dimensions of circular grooves for split-ring connectors**

Dimensions in millimetres

| Split-ring | Dimensions of groove | | |
|---|---|---|---|
| | Inside diameter | Width | Depth |
| 64 | 65.0 | 4.6 | 9.5 |
| 102 | 104.0 | 5.3 | 12.7 |

When assessing the effective cross-section of multiple connector joints, all connectors and their bolts that lie within a distance of 0.75 connector diameters, measured parallel to the grain, from a given cross-section should be considered as occurring at that cross-section. Then the effective cross-section should be determined by deducting the given net projected areas of the connector grooves and bolt holes from the gross area of the cross-section being considered.

### 6.8.3 Connector spacing

#### 6.8.3.1 *Spacing*

Associated with each size of split-ring connector is a standard end distance, edge distance and spacing between connectors which permit the basic load to apply. These standard distances are given in Table 91, Table 92 and Table 93. If the end distance, edge distance or spacing is less than the standard, the basic load should be modified (see **6.8.5**).

#### 6.8.3.2 *End and edge distances*

End and edge distances for connectors are defined in **6.7.3.2** and **6.7.3.3**.

### 6.8.4 Timber-to-timber joints

#### 6.8.4.1 *Connector unit*

A connector unit consists of one split-ring connector with its bolt in single shear in a timber-to-timber joint.

#### 6.8.4.2 *Assembly*

Chips and shavings should be removed and the split-rings should be expanded before insertion into the grooves.

#### 6.8.4.3 *Basic loads*

The basic loads parallel and perpendicular to the grain for split-ring connector units are given in Table 94 for timber members satisfying the requirements for strength classes C14 to D70.

Where the load is inclined at an angle $\alpha$ to the grain of the timber, the basic load $F$ should be determined from the equation given in **6.6.4.1**.

The basic loads given in this clause for each split-ring connector unit should be modified in accordance with **6.8.5** to determine the permissible load for a joint.

**Table 91 — End distances for split-ring and shear-plate connectors**

| Type of end distance | Angle [a] of load to grain $\alpha$ | End distance mm | | | |
|---|---|---|---|---|---|
| | | Connector size | | | |
| | | 64 mm split-ring or 67 mm shear-plate | | 102 mm split-ring or 102 mm shear-plate | |
| | degrees | Minimum | Standard | Minimum | Standard |
| Unloaded | 0 | 64 | 102 | 83 | 140 |
| | 45 | 67 | 121 | 86 | 159 |
| | 90 | 70 | 140 | 89 | 178 |
| Loaded | 0 to 90 | 70 | 140 | 89 | 178 |

[a] For intermediate angles, values should be obtained by linear interpolation.

**Table 92 — Edge distances for split-ring and shear-plate connectors**

| Type of edge distance | Angle [a] of load to grain $\alpha$ | Edge distance mm | | | |
|---|---|---|---|---|---|
| | | Connector size | | | |
| | | 64 mm split-ring or 67 mm shear-plate | | 102 mm split-ring or 102 mm shear-plate | |
| | degrees | Minimum | Standard | Minimum | Standard |
| Unloaded | 0 to 90 | 44 | 44 | 70 | 70 |
| Loaded | 0 | 44 | 44 | 70 | 70 |
| | 15 | 44 | 54 | 70 | 79 |
| | 30 | 44 | 64 | 70 | 87 |
| | 45 to 90 | 44 | 70 | 70 | 95 |

[a] For intermediate angles, values should be obtained by linear interpolation.

**Table 93 — Spacing modification factor, $K_S$, for split-ring and shear-plate connectors**

| Angle of load to grain $\alpha$ | Angle [a] of connector axis to grain $\theta$ | Spacing mm | | | | | |
|---|---|---|---|---|---|---|---|
| | | $K_S$ = 0.75 | $K_S$ = 0.80 | $K_S$ = 0.85 | $K_S$ = 0.90 | $K_S$ = 0.95 | $K_S$ = 1.00 |
| degrees | degrees | Minimum | | | | | Standard |
| **64 mm split-ring or 67 mm shear-plate** | | | | | | | |
| 0 | 0 | 89 | 105 | 121 | 140 | 156 | 171 |
| | 15 | 89 | 102 | 117 | 130 | 146 | 157 |
| | 30 | 89 | 98 | 108 | 114 | 124 | 132 |
| | 45 | 89 | 92 | 95 | 105 | 108 | 112 |
| | 60 | 89 | 92 | 92 | 95 | 95 | 98 |
| | 75 | 89 | 89 | 89 | 92 | 92 | 91 |
| | 90 | 89 | 89 | 89 | 89 | 89 | 89 |
| 15 | 0 | 89 | 102 | 114 | 127 | 140 | 152 |
| | 15 | 89 | 102 | 111 | 124 | 133 | 145 |
| | 30 | 89 | 98 | 105 | 114 | 124 | 129 |
| | 45 | 89 | 95 | 98 | 105 | 108 | 114 |
| | 60 | 89 | 92 | 95 | 98 | 102 | 103 |
| | 75 | 89 | 92 | 92 | 95 | 95 | 97 |
| | 90 | 89 | 89 | 92 | 92 | 95 | 95 |
| 30 | 0 | 89 | 98 | 105 | 114 | 124 | 130 |
| | 15 | 89 | 95 | 105 | 111 | 121 | 127 |
| | 30 | 89 | 95 | 102 | 108 | 114 | 119 |
| | 45 | 89 | 92 | 95 | 105 | 108 | 111 |
| | 60 | 89 | 92 | 95 | 98 | 102 | 104 |
| | 75 | 89 | 92 | 92 | 95 | 95 | 99 |
| | 90 | 89 | 92 | 92 | 95 | 95 | 98 |
| 45 | 0 | 89 | 92 | 95 | 102 | 105 | 108 |
| | 15 | 89 | 92 | 95 | 102 | 105 | 108 |
| | 30 | 89 | 92 | 95 | 102 | 105 | 107 |
| | 45 | 89 | 92 | 95 | 102 | 105 | 106 |
| | 60 | 89 | 92 | 95 | 98 | 102 | 106 |
| | 75 | 89 | 92 | 95 | 98 | 102 | 105 |
| | 90 | 89 | 92 | 95 | 98 | 102 | 105 |
| 60 to 90 | 0 | 89 | 89 | 89 | 89 | 89 | 89 |
| | 15 | 89 | 89 | 89 | 89 | 89 | 90 |
| | 30 | 89 | 89 | 89 | 92 | 92 | 93 |
| | 45 | 89 | 92 | 92 | 95 | 95 | 97 |
| | 60 | 89 | 92 | 92 | 95 | 98 | 102 |
| | 75 | 89 | 92 | 95 | 98 | 102 | 106 |
| | 90 | 89 | 92 | 95 | 102 | 105 | 108 |

[a] For intermediate angles, values should be obtained by linear interpolation.

**Table 93 — Spacing modification factor, $K_S$, for split-ring and shear-plate connectors** (*continued*)

| Angle of load to grain $\alpha$ degrees | Angle [a] of connector axis to grain $\theta$ degrees | Spacing mm | | | | | |
|---|---|---|---|---|---|---|---|
| | | $K_S$ = 0.75 Minimum | $K_S$ = 0.80 | $K_S$ = 0.85 | $K_S$ = 0.90 | $K_S$ = 0.95 | $K_S$ = 1.00 Standard |
| **102 mm split-ring or 102 mm shear-plate** | | | | | | | |
| 0 | 0 | 127 | 146 | 168 | 187 | 210 | 229 |
| | 15 | 127 | 143 | 162 | 178 | 197 | 213 |
| | 30 | 127 | 140 | 149 | 162 | 171 | 183 |
| | 45 | 127 | 133 | 140 | 146 | 149 | 157 |
| | 60 | 127 | 130 | 133 | 133 | 142 | 140 |
| | 75 | 127 | 127 | 127 | 130 | 130 | 130 |
| | 90 | 127 | 127 | 127 | 127 | 127 | 127 |
| 15 | 0 | 127 | 143 | 159 | 171 | 187 | 203 |
| | 15 | 127 | 140 | 152 | 168 | 181 | 195 |
| | 30 | 127 | 137 | 146 | 159 | 168 | 178 |
| | 45 | 127 | 133 | 140 | 149 | 156 | 161 |
| | 60 | 127 | 130 | 133 | 140 | 142 | 147 |
| | 75 | 127 | 130 | 133 | 133 | 137 | 140 |
| | 90 | 127 | 130 | 130 | 133 | 137 | 137 |
| 30 | 0 | 127 | 137 | 146 | 159 | 168 | 178 |
| | 15 | 127 | 137 | 146 | 156 | 165 | 175 |
| | 30 | 127 | 133 | 143 | 149 | 159 | 168 |
| | 45 | 127 | 133 | 140 | 146 | 152 | 160 |
| | 60 | 127 | 133 | 137 | 143 | 146 | 152 |
| | 75 | 127 | 130 | 137 | 140 | 145 | 148 |
| | 90 | 127 | 130 | 137 | 140 | 143 | 146 |
| 45 | 0 | 127 | 133 | 137 | 143 | 146 | 152 |
| | 15 | 127 | 133 | 137 | 143 | 146 | 152 |
| | 30 | 127 | 133 | 137 | 143 | 146 | 153 |
| | 45 | 127 | 133 | 137 | 143 | 146 | 154 |
| | 60 | 127 | 133 | 140 | 146 | 149 | 155 |
| | 75 | 127 | 133 | 140 | 146 | 149 | 156 |
| | 90 | 127 | 133 | 140 | 146 | 149 | 156 |
| 60 to 90 | 0 | 127 | 127 | 127 | 127 | 127 | 127 |
| | 15 | 127 | 127 | 127 | 127 | 127 | 129 |
| | 30 | 127 | 127 | 130 | 130 | 133 | 134 |
| | 45 | 127 | 130 | 133 | 133 | 137 | 142 |
| | 60 | 127 | 133 | 137 | 143 | 146 | 152 |
| | 75 | 127 | 133 | 140 | 146 | 152 | 161 |
| | 90 | 127 | 133 | 143 | 149 | 159 | 165 |

[a] For intermediate angles, values should be obtained by linear interpolation.

**Table 94 — Basic loads for one split-ring connector unit**

| Split-ring diameter | Nominal bolt size and thread diameter | Actual thickness of members [a] (mm) | | Basic load (kN) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connector on one side only | Connectors on both sides and on same bolt | C14 | | C16/18/22 | | C24 | | C27/30/35/40 | | D30/35/40 | | D50/60/70 | |
| | | | | Angle of load to grain | | | | | | | | | | | |
| mm | mm | | | 0° | 90° | 0° | 90° | 0° | 90° | 0° | 90° | 0° | 90° | 0° | 90° |
| 64 | M12 | 22 | 32 | 5.23 | 3.66 | 5.38 | 3.77 | 5.85 | 4.09 | 6.28 | 4.39 | 8.92 | 6.25 | 10.99 | 7.70 |
| | | 25 | 40 | 6.32 | 4.42 | 6.51 | 4.55 | 7.06 | 4.95 | 7.58 | 5.31 | 10.80 | 7.55 | 13.31 | 9.31 |
| | | 29 | 50 | 7.68 | 5.38 | 7.91 | 5.54 | 8.58 | 6.01 | 9.21 | 6.45 | 13.10 | 9.18 | 16.15 | 11.31 |
| 102 | M20 | 29 | 41 | 10.10 | 7.04 | 10.38 | 7.25 | 11.22 | 7.87 | 12.04 | 8.45 | 17.20 | 12.00 | 21.20 | 14.79 |
| | | 32 | 50 | 11.50 | 8.01 | 11.82 | 8.25 | 12.78 | 8.95 | 13.72 | 9.61 | 19.50 | 13.70 | 24.03 | 16.89 |
| | | 36 | 63 | 13.50 | 9.42 | 13.88 | 9.70 | 15.02 | 10.52 | 16.12 | 11.30 | 23.00 | 16.10 | 28.35 | 19.84 |
| | | 40 | 72 | 14.30 | 9.98 | 14.72 | 10.26 | 15.98 | 11.12 | 17.14 | 11.94 | 24.30 | 17.00 | 29.95 | 20.95 |
| | | 41 | 75 | 14.40 | 10.10 | 14.82 | 10.38 | 16.08 | 11.22 | 17.26 | 12.04 | 24.50 | 17.20 | 30.20 | 21.20 |

[a] For intermediate thicknesses, values may be obtained by linear interpolation.

### 6.8.5 Permissible load for a joint

Where more than one connector is used with the same bolt in a multi-member joint, the appropriate permissible load should be calculated for each connector unit and these loads should be added together for those members acting alone.

The permissible load for a split-ring connectored joint, $F_{adm}$, should be determined as the sum of the permissible loads for each connector unit in the joint, where each permissible connector unit load should be calculated as:

$$F_{adm} = F \times K_{62} \times K_{63} \times K_{64} \times K_{65}$$

where the basic load for a split-ring connector unit, $F_b$, is taken from **6.8.4.3**, and

$K_{62}$ is the modification factor for duration of loading;

$K_{63}$ is the modification factor for moisture content;

$K_{64}$ is the modification factor for end distance, edge distance and spacing;

$K_{65}$ is the modification factor for the number of connectors in each line.

For duration of loading:

$K_{62}$ = 1.00 for long-term loads;

$K_{62}$ = 1.25 for medium-term loads;

$K_{62}$ = 1.50 for short- or very short-term loads.

For moisture content:

$K_{63}$ = 1.0 for a joint in service class 1 or 2;

$K_{63}$ = 0.7 for a joint in service class 3.

For end distance, edge distance and spacing:

if the end distance, edge distance and/or centre spacing of the connectors are less than the relevant standard values given in Table 91, Table 92 and Table 93, respectively, the modification factor, $K_{64}$, should have the lowest of the values for $K_S$, $K_C$ and $K_D$ given in Table 93, Table 95 and Table 96, respectively. In no case should the distances and spacing be less than the minimum values given in Table 91, Table 92 and Table 93. No increase in load is permitted if end distance, edge distance or centre spacing exceeds the standard values.

If split-ring connectors are used in green hardwood, the standard end distance should be multiplied by 1.5. One-half of this increased end distance should be taken as the minimum end distance, with a permissible load of one-half of that permitted for the standard end distance.

For the number of connectors in each line:

where a number of connector units of the same size are symmetrically arranged in one or more lines parallel to the line of action of the load in a primarily axially loaded member of a structural framework (see **1.6.11**), then:

$$K_{65} = 1 - \frac{(3n - 1)}{100} \text{ for } n < 10$$

$$K_{65} = 0.7 \text{ for } n \geq 10$$

where $n$ is the number of connector units in each line.

In all other loading cases where more than one split-ring connector unit is used in a joint:

$$K_{65} = 1.0$$

**Table 95 — End distance modification factor, $K_C$, for split-ring and shear-plate connectors**

| End distance | Value of $K_C$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unloaded | | | | | | Loaded | |
| | Connector size | | | | | | Connector size | |
| | 64 mm split-ring or 67 mm shear-plate | | | 102 mm split-ring or 102 mm shear-plate | | | 64 mm split-ring or 67 mm shear-plate | 102 mm split-ring or 102 mm shear-plate |
| | Angle [a] of load to grain, $\alpha$ | | | | | | | |
| mm | 0° | 45° | 90° | 0° | 45° | 90° | 0° to 90° | 0° to 90° |
| 60 | | | | | | | | |
| 65 | 0.63 | | | | | | | |
| 70 | 0.68 | 0.64 | 0.62 | | | | 0.62 | |
| 75 | 0.73 | 0.68 | 0.65 | | | | 0.65 | |
| 80 | 0.78 | 0.71 | 0.67 | | | | 0.67 | |
| 85 | 0.83 | 0.75 | 0.70 | 0.63 | | | 0.70 | |
| 90 | 0.88 | 0.78 | 0.73 | 0.67 | 0.64 | 0.62 | 0.73 | 0.62 |
| 95 | 0.93 | 0.82 | 0.76 | 0.70 | 0.67 | 0.65 | 0.76 | 0.65 |
| 100 | 0.98 | 0.85 | 0.78 | 0.73 | 0.69 | 0.67 | 0.78 | 0.67 |
| 105 | 1.00 | 0.89 | 0.81 | 0.77 | 0.72 | 0.69 | 0.81 | 0.69 |
| 110 | 1.00 | 0.92 | 0.84 | 0.80 | 0.74 | 0.71 | 0.84 | 0.71 |
| 115 | 1.00 | 0.96 | 0.86 | 0.83 | 0.77 | 0.73 | 0.86 | 0.73 |
| 120 | 1.00 | 0.99 | 0.89 | 0.87 | 0.80 | 0.75 | 0.89 | 0.75 |
| 125 | 1.00 | 1.00 | 0.92 | 0.90 | 0.82 | 0.77 | 0.92 | 0.77 |
| 130 | 1.00 | 1.00 | 0.95 | 0.93 | 0.85 | 0.80 | 0.95 | 0.80 |
| 135 | 1.00 | 1.00 | 0.97 | 0.97 | 0.88 | 0.82 | 0.97 | 0.82 |
| 140 | 1.00 | 1.00 | 1.00 | 1.00 | 0.90 | 0.84 | 1.00 | 0.84 |
| 145 | 1.00 | 1.00 | 1.00 | 1.00 | 0.93 | 0.86 | 1.00 | 0.86 |
| 150 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.88 | 1.00 | 0.88 |
| 155 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 0.90 | 1.00 | 0.90 |
| 160 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.92 | 1.00 | 0.92 |
| 165 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.94 | 1.00 | 0.94 |
| 170 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 1.00 | 0.97 |
| 175 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 1.00 | 0.99 |
| 180 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

[a] For intermediate angles and end distances, values may be obtained by linear interpolation.

**Table 96 — Loaded edge distance modification factor, $K_D$, for split-ring and shear-plate connectors**

| Edge distance [a] | Value of $K_D$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Connector size | | | | | | | |
| | 64 mm split-ring or 67 mm shear-plate | | | | 102 mm split-ring or 102 mm shear-plate | | | |
| | Angle [a] of load to grain, $\alpha$ | | | | | | | |
| mm | 0° | 15° | 30° | 45° to 90° | 0° | 15° | 30° | 45° to 90° |
| 45 | 1.00 | 0.94 | 0.89 | 0.83 | | | | |
| 50 | 1.00 | 0.98 | 0.93 | 0.87 | | | | |
| 55 | 1.00 | 1.00 | 0.96 | 0.90 | | | | |
| | | | | | | | | |
| 60 | 1.00 | 1.00 | 0.99 | 0.93 | | | | |
| 65 | 1.00 | 1.00 | 1.00 | 0.97 | | | | |
| 70 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.94 | 0.89 | 0.83 |
| | | | | | | | | |
| 75 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 0.92 | 0.86 |
| 80 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.90 |
| 85 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.93 |
| | | | | | | | | |
| 90 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 |
| 95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

[a] For intermediate angles and edge distances, values may be obtained by linear interpolation.

## 6.9 Shear-plate connector joints

### 6.9.1 General

#### 6.9.1.1 *Connector sizes*

The recommendations contained in **6.9** are applicable to the sizes of shear-plate connectors given in Table 97 and conforming to BS 1579.

**Table 97 — Sizes of shear-plate connectors and minimum sizes of washers**

| Nominal size of connector | Nominal size and thread diameter of bolt | Minimum size of round or square washers | |
|---|---|---|---|
| | | Diameter or length of side | Thickness |
| mm | | mm | mm |
| 67 | M20 | 75 | 5 |
| 102 | M20 | 75 | 5 |

NOTE The sizes given in this table are metric conversions of the imperial sizes given in BS 1579.

#### 6.9.1.2 *Bolts and washers*

The nominal diameter of the bolts to be used with shear-plate connectors are given in Table 97. Bolt holes should be as close as practicable to the nominal diameter of the bolt, and in no case more than 2.0 mm larger than the bolt diameter.

Round or square washers should be fitted between the timber and the head and nut of the bolt. The minimum size of washer to be used with each connector is given in Table 97.

Connectors should not bear on the threads of bolts.

#### 6.9.1.3 *Joint preparation*

To prepare a connectored joint, the positions of the bolt holes should be set out accurately with reference to the point of intersection of the centre-lines of the members. One of the following two procedures should be used when drilling the bolt holes:

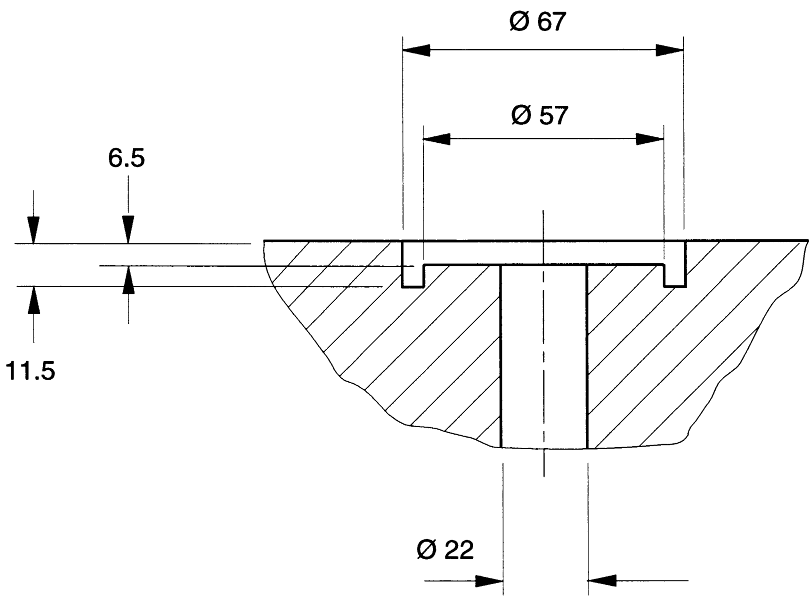
a) fit the members together in their correct positions and clamp while drilling the bolt holes through all the members;

b) drill the bolt holes in the individual members using jigs or templates to locate the bolt holes accurately.

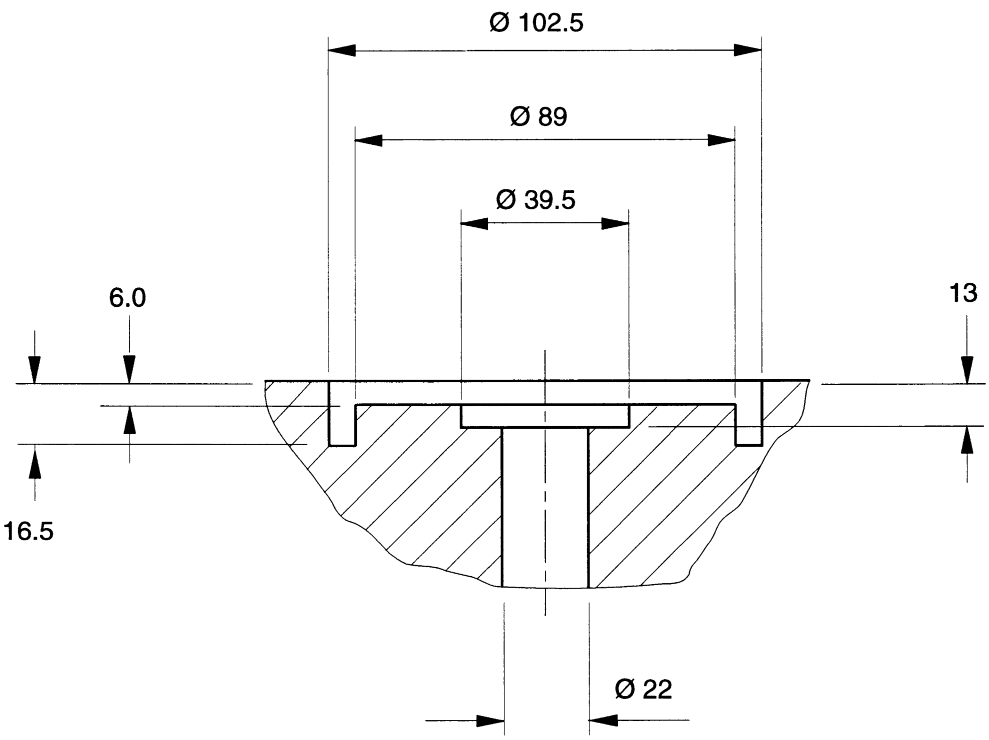
Bolt holes should be within 2 mm of their specified position.

The contact surfaces of the timber members should be recessed to the dimensions shown in Figure 8.

The recesses for shear-plate may be cut simultaneously with the drilling of the bolt holes if procedure b) is used.




a) Recess for 67 mm connector unit




b) Recess for 102 mm connector unit

All dimensions are in millimetres.

**Figure 8 — Dimensions of circular recesses for shear-plate connector units conforming to BS 1579**

### 6.9.2 Effective cross-section

The effective cross-section of each member at a joint should be determined by deducting the projected area from the gross area of the cross-section of the connector recess (i.e. 770 mm$^2$ for each 67 mm shear-plate, or 1 690 mm$^2$ for each 102 mm shear-plate) and the projected area of the bolt hole not within the projected area of the recess. The depths of the connector recess are 11.5 mm and 16.5 mm for the 67 mm and 102 mm shear-plates, respectively.

When assessing the effective cross-section of multiple connector joints, all connectors and their bolts that lie within a distance of 0.75 connector diameters, measured parallel to the grain from a given cross-section should be considered as occurring at that cross-section. Then the effective cross-section should be determined by deducting the given net projected areas of the connector recesses and bolt holes from the gross area of the cross-section being considered.

### 6.9.3 Connector spacing

**6.9.3.1** ***Spacing***

Associated with each size of shear-plate connector is a standard end distance, edge distance and spacing between connectors which permit the basic load to apply. These standard distances are given in Table 91, Table 92 and Table 93.

If the end distance, edge distance or spacing is less than the standard, the basic load should be modified (see **6.9.6**).

**6.9.3.2** ***End and edge distances***

End and edge distances for connectors are defined in **6.7.3.2** and **6.7.3.3**.

### 6.9.4 Timber-to-timber joints

**6.9.4.1** ***Connector unit***

A connector unit consists of two shear-plates, used back to back with the bolt in single shear, in a timber-to-timber joint.

**6.9.4.2** ***Assembly***

Chips and shavings should be removed before inserting the shear-plate into the recess.

**6.9.4.3** ***Basic loads***

The basic loads parallel and perpendicular to the grain for shear-plate connector units are given in Table 98 for timber members satisfying the requirements for strength classes C14 to D70.

Where the load is inclined at an angle $\alpha$ to the grain of the timber, the basic load, $F$, should be determined from the equations given in **6.6.4.1**.

The basic loads given in this clause for each shear-plate connector unit should be modified in accordance with **6.9.6** to determine the permissible load for a joint.

### 6.9.5 Steel plate-to-timber joints

**6.9.5.1** ***Connector unit***

A connector unit consists of one shear-plate with its bolt in single shear in a steel plate-to-timber joint.

**6.9.5.2** ***Steel plates***

Steel plates should have adequate strength and be designed in accordance with BS 449-2.

**6.9.5.3** ***Basic loads***

The basic loads for each shear-plate connector unit in a steel plate-to-timber joint should be obtained in accordance with **6.9.4.3** and modified in accordance with **6.9.6** to determine the permissible load for the joint.

**Table 98 — Basic loads [a] for one shear-plate connector unit**

| Shear-plate diameter mm | Nominal bolt size and thread diameter mm | Actual thickness of member mm | | Basic load parallel to grain kN | | | | | | Basic load perpendicular to grain kN | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connector on one side only | Connectors on both sides and on same bolt | C14 | C16/18/22 | C24 | C27/30/35/40 | D30/35/40 | D50/60/70 | C14 | C16/18/22 | C24 | C27/30/35/40 | D30/35/40 | D50/60/70 |
| 67 | M20 | — | 41 | 6.45 | 6.64 | 7.20 | 7.73 | 11.00 | 13.56 | 4.51 | 4.64 | 5.05 | 5.42 | 7.70 | 9.49 |
| | | — | 50 | 7.72 | 7.95 | 8.62 | 9.26 | 11.90 | 14.67 | 5.40 | 5.56 | 6.04 | 6.49 | 9.22 | 11.36 |
| | | — | 63 | 8.21 | 8.45 | 9.18 | 9.86 | 11.90 | 14.67 | 5.75 | 5.92 | 6.42 | 6.89 | 9.80 | 12.08 |
| | | 41 | 67 | 8.32 | 8.56 | 9.30 | 9.97 | 11.90 | 14.67 | 5.82 | 5.99 | 6.51 | 6.99 | 9.93 | 12.24 |
| 102 | M20 | — | 44 | 8.32 | 8.57 | 9.30 | 9.98 | 14.20 | 17.50 | 5.83 | 6.00 | 6.51 | 6.99 | 9.94 | 12.25 |
| | | — | 50 | 9.18 | 9.44 | 10.24 | 10.98 | 15.60 | 19.23 | 6.42 | 6.61 | 7.18 | 7.71 | 11.00 | 13.56 |
| | | — | 63 | 10.50 | 10.82 | 11.78 | 12.66 | 18.00 | 22.19 | 7.38 | 7.60 | 8.25 | 8.86 | 12.60 | 15.53 |
| | | 41 | — | 11.70 | 12.04 | 13.06 | 14.02 | 19.90 | 24.53 | 8.17 | 8.41 | 9.13 | 9.80 | 13.90 | 17.13 |
| | | — | 75 | 11.90 | 12.24 | 13.26 | 14.24 | 20.30 | 25.02 | 8.33 | 8.57 | 9.31 | 10.00 | 14.20 | 17.50 |
| | | 44 | 92 | 12.50 | 12.88 | 14.02 | 15.06 | 21.40 | 26.38 | 8.79 | 9.05 | 9.84 | 10.56 | 15.00 | 18.49 |

[a] For intermediate thicknesses, values may be obtained by linear interpolation.

### 6.9.6 Permissible load for a joint

Where more than one connector is used with the same bolt in a multi-member joint, the appropriate permissible load should be calculated for each connector unit, and these loads should be added together.

Under no circumstances should the permissible load for a shear-plate connector unit exceed the limiting values given in Table 99. The permissible load for a shear-plate connectored joint, $F_{adm}$, should be determined as the sum of the permissible loads for each connector unit in the joint, where each permissible connector unit load should be calculated as:

$$F_{adm} = F \times K_{66} \times K_{67} \times K_{68} \times K_{69}$$

where the basic load for a shear-plate connector unit, $F$, is taken from **6.9.4.3** or **6.9.5.3**, as appropriate, and

$K_{66}$ is the modification factor for duration of loading;

$K_{67}$ is the modification factor for moisture content;

$K_{68}$ is the modification factor for end distance, edge distance and centre spacing;

$K_{69}$ is the modification factor for the number of connectors in each line.

For duration of loading:

$K_{66}$ = 1.00 for long-term loads;

$K_{66}$ = 1.25 for medium-term loads;

$K_{66}$ = 1.50 for short- and very short-term loads.

For moisture content:

$K_{67}$ = 1.0 for a joint in service class 1 or 2;

$K_{67}$ = 0.7 for a joint in service class 3.

For end distance, edge distance and spacing:

if the end distance, edge distance and/or centre spacing of the connectors are less than the relevant standard values given in Table 91, Table 92 and Table 93, respectively, the modification factor, $K_{68}$, should have the lowest of the values for $K_S$, $K_C$ and $K_D$ given in Table 93, Table 95 and Table 96, respectively. In no case should the distances and spacing be less than the minimum values given in Table 91, Table 92 and Table 93. No increase in load is permitted if end distance, edge distance or centre spacing exceeds the standard values.

If shear-plate connectors are used in green hardwood, the standard end distance should be multiplied by 1.5. One-half of this increased end distance should be taken as the minimum end distance, with a permissible load of one-half of that permitted for the standard end distance.

For the number of connectors in each line:

where a number of connector units of the same size are symmetrically arranged in one or more lines parallel to the line of action of the load in a primarily axially loaded member of a structural framework (see **1.6.11**), then:

$$K_{69} = 1 - \frac{(3n - 1)}{100} \text{ for } n < 10$$

$$K_{69} = 0.7 \text{ for } n \geq 10$$

where $n$ is the number of connector units in each line.

In all other loading cases where more than one shear-plate connector unit is used in a joint:

$K_{69}$ = 1.0

**Table 99 — Limiting values for permissible loads on one shear-plate connector unit**

| Shear-plate diameter<br>mm | Nominal bolt size | All loading except short- and very short-term loading<br>kN | All loading including short- and very short-term loading<br>kN |
|---|---|---|---|
| 67 | M20 | 12.9 | 17.2 |
| 102 | M20 | 22.1 | 29.5 |

## 6.10 Glued joints

### 6.10.1 Laterally loaded joints

#### 6.10.1.1 *General*

Joints in structural components made from separate pieces of timber, plywood and other panel products that are fastened together with glue (e.g. box beams, single web beams, stressed skin panels, glued gussets) should be manufactured in accordance with BS 6446.

The provisions of this clause for glued structural joints apply only to the softwood species listed in Table A.1 (with the exception of excessively resinous pieces), to the plywoods listed in section **4**, and to the other panel products described in section **5**. For the gluing of hardwoods and resinous softwoods, advice should be sought from the glue manufacturer.

The provisions of this clause are limited to the following structural joints:

a) between solid or laminated timber members of which the dimension at right angles to the plane of the glueline is not greater than 50 mm;

b) between solid or laminated timber members of any dimension and plywood or wood particleboard no thicker than 29 mm;

c) between solid or laminated timber members of any dimension and tempered hardboard no thicker than 8 mm;

d) between plywood members of any thickness;

e) between tempered hardboard members of any thickness;

f) between wood particleboard members of any thickness.

Consideration should be given to the possibility of differential shrinkage, distortion and stress concentrations at glued joints.

When mechanical fasteners are present in a glued joint they should not be considered as contributing to the strength of the joint.

#### 6.10.1.2 *Adhesives*

The adhesive used should be appropriate to the environment in which the joint will be used. Table 100 details four exposure categories, the permitted adhesives and the British Standard classifications and references.

Designers should ensure that, in the case of an MR type of adhesive conforming to BS 1204, a particular formulation is suitable for the service conditions and for the intended life of the structure.

**6.10.1.3** ***Timber-to-timber joints***

Eccentric glued lap joints which induce a tensile component of stress perpendicular to the plane of the glueline should not be permitted.

The permissible shear stress for adhesives in lap joints, when the components of the joint are loaded parallel to the grain, should be taken as the lesser of the permissible shear stresses parallel to the grain.

When one face of the joint is loaded at an angle to the grain, the permissible shear stress for the glueline should be calculated using the following equation:

$$\tau_{a} = \tau_{\mathrm{adm},\parallel} (1 - 0.67 \sin a)$$

where

| | |
|---|---|
| $a$ | is the angle between the direction of the load and the grain of the piece; |
| $\tau_{\mathrm{adm},\parallel}$ | is the permissible shear parallel to the grain stress for the timber. |

Where bonding pressure is generated by nails or staples, the permissible shear stress for the glueline should be multiplied by the nail/glue modification factor, $K_{70}$, which has the value 0.9.

**6.10.1.4** ***Timber to plywood or tempered hardboard or wood particleboard joints***

The permissible shear stress for a joint loaded parallel to the grain of the timber member should be taken as the permissible shear parallel to the grain stress for the timber, or the appropriate rolling shear stress for the plywood or tempered hardboard or wood particleboard, whichever has the lower value. When the timber is loaded at an angle to the grain, the permissible shear stress for the timber member should be calculated as for the glueline in **6.10.1.3**. The rolling shear stress for plywood or tempered hardboard or wood particleboard is independent of the direction of loading within the plane of the board.

Where bonding pressure is generated by nails or staples, the permissible shear stress for the glueline should be multiplied by the modification factor, $K_{70}$, which has the value 0.9.

**6.10.1.5** ***Plywood to plywood, tempered hardboard to tempered hardboard and particleboard to particleboard joints***

The permissible shear stress for a joint should be taken as the appropriate rolling shear stress for the plywood or tempered hardboard or wood particleboard. Where bonding pressure is generated by nails or staples, the permissible shear stress for the glueline should be multiplied by the modification factor, $K_{70}$, which has the value 0.9.

### 6.10.2 Finger joints

Finger joints should be manufactured in accordance with BS EN 385.

Finger joints should not be used in principal members, or other members acting alone, where failure of a single joint could lead to collapse, except where the joints have been manufactured under a third-party quality control scheme.

Finger joints should have characteristic bending strengths of not less than the characteristic bending strength of the strength class for the timber being jointed (see Table 101) when tested in accordance with BS EN 385. Alternatively, finger joints should have bending efficiency ratings (regardless of the type of loading) equal to or greater than the values given in Table 102.

The efficiency ratings which can be attained by some common finger joint profiles are given in Annex C.

Finger joint efficiencies for compression parallel to the grain are also given in Table C.1. The required performance is the same as for joints in flexural members (see Table 102).

For hardwood species, assurance should be sought from the adhesive manufacturer as to the suitability and long-term durability of the adhesive for the particular hardwood species and exposure conditions. In no case should a finger joint profile with an efficiency rating of less than 50 % be used.

It may be assumed that the presence of finger joints in a cross-section does not affect its modulus of elasticity, and the full cross-section may be used in calculations.

**Table 100 — Permissible adhesive types**

| Intended use | Exposure category | Typical exposure conditions | Adhesive type and specification |
|---|---|---|---|
| Exterior | High hazard | Full exposure to the weather (e.g. marine structures and exterior structures where the glueline is exposed to the elements).<br>Glued structures other than glued laminated members are not recommended for use under this exposure condition. | Phenolic and aminoplastic adhesives satisfying the specification for type I in accordance with BS EN 301. |
| | Low hazard | Protected from sun and rain, roofs of open sheds and porches.<br>Temporary structures such as concrete formwork. | Phenolic and aminoplastic adhesives satisfying the specification for type I or type II in accordance with BS EN 301.<br>Phenolic and aminoplastic adhesives satisfying the specification for type MR in accordance with BS 1204 [a]. |
| Interior | High hazard | Building with warm and damp conditions where a moisture content of 18 % is exceeded and where the glueline temperature can exceed 50 °C (e.g. laundries and unventilated roof spaces).<br>Chemically polluted atmospheres (e.g. chemical works, dye works and swimming pools).<br>External single leaf walls with protective cladding. | Phenolic and aminoplastic adhesives satisfying the specification for type I in accordance with BS EN 301. |
| | Low hazard | Heated and ventilated buildings where the moisture content of the wood will not exceed 18 % and where the temperature of the glueline will remain below 50 °C (e.g. interiors of houses, halls, churches and other buildings).<br>Inner leaf of cavity walls. | Phenolic and aminoplastic adhesives satisfying the specification for type I or type II in accordance with BS EN 301.<br>Phenolic and aminoplastic adhesives satisfying the specification for type MR in accordance with BS 1204 [a].<br>Casein [a]. |

[a] The designer should ensure that a particular formulation is suitable for the service conditions and for the intended life of the structure.

**Table 101 — Characteristic bending strengths**

| Strength class | Characteristic bending strength N/mm$^2$ |
|---|---|
| C14 | 14.0 |
| C16 | 16.0 |
| C18 | 18.0 |
| TR20 | 20.0 |
| C22 | 22.0 |
| C24 | 24.0 |
| TR26 | 27.0 |
| C27 | 27.0 |
| C30 | 30.0 |
| C35 | 35.0 |
| C40 | 40.0 |
| D30 | 30.0 |
| D35 | 35.0 |
| D40 | 40.0 |
| D50 | 50.0 |
| D60 | 60.0 |
| D70 | 70.0 |

**Table 102 — Minimum finger joint efficiencies required**

| Strength class | Minimum finger joint efficiency in bending % |
|---|---|
| D30 to D70 | See **3.4** |
| C30 | See **3.4** |
| TR26 and C27 | 75 |
| C18 to C24 and TR20 | 70 |
| C14 to C16 | 55 |

# Section 7. Workmanship, inspection and maintenance

## 7.1 General

This section gives recommendations for the preparation, fabrication, inspection, storage, handling and maintenance of materials and components.

The recommendations given in this section are necessary conditions for the applicability of the permissible stresses and loads given elsewhere in BS 5268-2.

Materials should be applied, used and fixed in such a way as to perform adequately the functions for which they are designed.

Workmanship in fabrication, preparation and installation of materials should conform in all respects to accepted good practice.

There should be adequate supervision throughout the preparation and construction of the structure to ensure that it conforms to the principles and practical considerations of the design.

Members which are damaged, crushed or split beyond the limits permitted for similar defects in the grading should be rejected or repaired to the satisfaction of the designers and approving authority.

For particle board, oriented strand board (OSB), cement bonded particleboard and wood fibreboards, the recommendations in BS 7916 should be followed.

## 7.2 Moisture content

### 7.2.1 General

At the time of erection, the moisture content of timber should not exceed the maximum given in **1.6.5**. Moisture contents at time of fabrication may be determined by specific requirements (e.g. adhesive performances and conditioning of tempered hardboard or wood particleboard), but should not normally exceed the limits given in **1.6.5**.

### 7.2.2 Measurement of moisture content

The determination of moisture content by a properly calibrated moisture meter used in accordance with the manufacturer's instructions will normally be considered sufficiently accurate for the purposes of BS 5268-2. Probes of a length appropriate to the dimensions of the member should be used (see note to Table 1).

Where a more accurate average determination of moisture content has to be made, and for meter calibration, the oven dry method detailed in Annex H should be used.

## 7.3 Machining and preparation

### 7.3.1 General

The size, shape and finish of all members and materials should conform to the detailed drawings and specifications.

The cutting, notching or modification of members, other than that allowed by the drawings and specification or by items a) or b) of **2.10.9** and **2.11.7** should not be permitted.

Care should be taken to ensure that notches and holes are not so positioned in a member that the remainder of the cross-section contains a knot or other defect which will significantly affect its strength.

Dimensions and spacings should not be scaled from drawings.

### 7.3.2 Surfaces

Surfaces and contact areas of joints should be appropriate to the joint and jointing method.

### 7.3.3 Treatment of cut surfaces

The cutting of timber after preservative treatment should be avoided. However, when it is unavoidable, exposed untreated timber should be given a liberal application of suitable preservative in accordance with BS 5268-5.

### 7.3.4 Marking

When grade or other necessary identification marks are removed, provisions should be made for re-marking in accordance with BS EN 300, BS EN 312-4, -5, -6 or -7, BS EN 518, BS EN 519, BS EN 622-2, -3 or -5, BS EN 634-2, BS EN 636-1, -2 or -3 and BS 5756.

## 7.4 Joints

### 7.4.1 General

Wane, fissures, knots or other defects which have not been allowed for in the design, and which may affect significantly the load-carrying capacity, should not be permitted at a joint.

### 7.4.2 Mechanical joints

The spacing and pre-drilling of holes for nails, screws, and bolts should conform to the design drawings and to **6.4**, **6.5** and **6.6**.

Screws and bolts should be tightened so that members fit closely together. Washers should have a full bearing area, and the fasteners should, if necessary, be tightened again when the members have reached their equilibrium moisture content. Screws should be turned, not hammered, into pre-bored holes.

### 7.4.3 Connectored joints

The toothed-plate, split-ring and shear-plate connectored joints should be fitted in accordance with the design drawings and section **6**.

Care should be taken to ensure that recesses are accurately cut concentric with the bolt hole, and all chips and shavings are removed.

### 7.4.4 Glued joints

Joints in structural components made from separate pieces of timber, plywood or other wood based board that are fastened together with glue (e.g. box beams, single web beams, stressed skin panels, glued gussets) should be manufactured in accordance with BS 6446. Finger joints should be manufactured in accordance with BS EN 385.

## 7.5 Transportation, storage and handling

### 7.5.1 Protection of unfixed materials and components

Precautions should be taken during storage, prior to delivery, and on site to minimize changes in moisture content due to the weather. Rain, damp and direct sunlight are all potentially harmful to timber and wood-based components.

Materials and components should be stored on dry bases, and stacks should be evenly supported on bearers with spacer sticks at regular intervals. Stacks should be sheeted with tarpaulins or other impervious material so arranged to give full cover, but at the same time to permit free passage of air around and through the stack. Care should be taken not to deform stacked material.

Where it is essential that materials and components have low moisture contents, it may not be possible to maintain suitable conditions on site other than for short periods, and deliveries should be arranged accordingly.

### 7.5.2 Site storage

Carcassing timber delivered packaged, i.e. strapped, should not be stored in packaged form for lengthy periods. Where early use is not possible, packages should be opened and the timber should be open-piled and suitably protected together with any loose timber.

Plywood and other wood-based materials, whether packaged or otherwise, should be stored under cover for preference. Where this is not possible, storage in the original packages should be as described in **7.5**. Structural components should be stored undistorted and clear of the ground on levelled trestles, stillages or other suitable bearers. As with timber and plywood they should be sheeted with tarpaulins or other impervious material as described in **7.5**. Particular care should be taken to avoid damage to all materials and components during storage on site.

### 7.5.3 Handling

Undue distortion of components during transportation and handling should be avoided. Similarly, damage from chafing or slings should also be avoided. Where design assumptions for long, flexible or heavy components dictate certain methods of handling, lifting points should be marked on the components and methods of lifting should be shown on the design drawings.

### 7.5.4 Protection of installed materials and components

Installed components may be subjected temporarily to wetting, which may increase their moisture content. Provided that they are amply ventilated, the additional moisture should evaporate rapidly.

Temporary protection may be needed where components are installed before the structure is adequately weather-proofed.

Attention is drawn to the possibility of excessive creep or shrinkage occurring in long span flexural components if loaded before their moisture content is close to the expected end use condition.

## 7.6 Assembly and erection

The method of assembly and erection should be such as to ensure that the geometry of assembled components, as specified by the designer, is achieved correctly within the specified tolerances. During assembly and erection, no forces should be applied to the component which could cause the permissible stresses to be exceeded in that or any other component. Special care is necessary when handling framed arches and shaped beams.

Where design assumptions dictate certain methods and sequences of erection, full information concerning them should be included in the health and safety plan (see Foreword) as well as being shown on the design drawings.

## 7.7 Treatments

### 7.7.1 Preservative treatments

Preservative treatment should be in accordance with BS 5268-5.

### 7.7.2 Flame-retardant treatments

Flame retardants should be used under such conditions and in such a manner that they will not adversely affect other materials or processes.

Materials treated with flame retardants should not be freely exposed to the weather or to similar environmental conditions which may affect the performance of the treatment.

Attention is drawn to the possibility of corrosive reactions between some flame retardants and metallic fittings and to the possible adverse effect on structural properties.

### 7.7.3 Decorative treatments

Where structural timber is painted, varnished or otherwise decorated, the work should be in accordance with BS 6150. Care should be taken to ensure that paints, preservatives, flame retardants and glues are compatible.

### 7.7.4 Anti-corrosive treatments

The anti-corrosive treatment of metal fasteners and fittings should be sufficient to ensure their satisfactory performance and structural integrity throughout the intended life of the structure. The degree of protection required will depend on the dimensions of the fittings and the environment to which they are to be exposed.

## 7.8 Inspection

Reasonable facilities and access for inspection should be provided during and at completion of fabrication and erection of a structure. These facilities and access conditions should be agreed between the parties concerned.

## 7.9 Maintenance

Attention is drawn to the Construction (Design and Management) Regulations 1994 [2] (see Foreword) which require that the designer considers risks to the health and safety of persons engaged in the maintenance of the structure, that elements needing maintenance are recorded in the health and safety file, and that the designer provides safe means of access to such elements.

It is imperative that features of the construction which are essential to the structural performances of timber and timber-based components, e.g. vapour barriers, ventilators, etc., are maintained in an effective condition during the intended life of the structural timberwork.

The design should ensure that access is possible to those parts of the structure likely to require periodic inspection or maintenance.

The building owner should ensure periodic inspection of such features.

Structural metalwork should be periodically inspected. Corroded fittings should be thoroughly checked and treated with an anti-corrosive or, if necessary, replaced.

Bolts in structural timberwork may need to be periodically re-tightened if moisture contents in service fluctuate by more than 10 %. In all cases it is advisable to check the tightness of bolts some six weeks to eight weeks after completion of the structure, and access for this purpose should be provided. A second inspection about 12 months after completion is recommended in the case of large and heavy members.

The responsibility for maintenance service should be agreed between the parties concerned.

# Section 8. Testing

## 8.1 General

This section gives recommendations for load testing, although in the normal course of events, structures or parts of structures designed in accordance with BS 5268-2 are not required to be tested. Load testing is, however, an equally acceptable alternative to calculations, and in certain cases can be a more positive method of establishing the structural adequacy of a particular design.

The methods of testing given in this section are for structures or components fabricated partly or wholly from timber, plywood or other wood based panel products. They are not appropriate to the testing of individual pieces of timber, joints or structural models.

Testing may be necessary in circumstances which include:

a) where a structure or part of a structure is not amenable to calculation, or where calculation is deemed impracticable;

b) where materials or design methods are used other than those of the relevant specification or code of practice;

c) where there is doubt or disagreement as to whether the structure or some part of it conforms to design rules, or as to whether the quality of the materials is of the required standard;

d) where a routine check of a mass-produced structure or part of a structure is required by prior agreement between the client and the manufacturer.

Wherever possible, more than one structure of the same design should be tested to enable an assessment to be made of the likely variability in performance. All structures should be tested in accordance with **8.5.2** and **8.5.3** and with **8.5.4** or **8.9** as appropriate.

For design by testing of roof and floor decking, see **8.9**.

NOTE The load testing of structures and components conforms to BS EN 380.

## 8.2 Testing authority

Structural tests should be formulated, supervised and certified by an authority competent in structural testing and timber engineering.

## 8.3 Information required

A copy of the detailed drawings and the specification, together with any other data or information that might be required for the purpose of the test, should be deposited with the testing authority before the tests are commenced. Relevant data may include such items as service conditions or likely moisture content range for the timber; dead, imposed and wind loads and points of application; duration of loading; positions and method of support; fixing and bracing details, etc.

## 8.4 Quality and manufacture of test structure

The manufacture and assembly of the test structure should conform to the design specification, and the method used should simulate as closely as possible that which would be used in production. The materials and workmanship in the test structure should be, as far as practicable, of the minimum quality and dimensions allowed by the relevant specification. The testing authority may require evidence of quality to ensure that this recommendation is met. The testing authority may require the test structure to be replaced or modified, if, in their opinion, the structure is not representative of the minimum specification requirements.

Where it is impracticable to test the complete structure, a representative part may be selected for test. This should incorporate the essential structural elements and should be agreed in advance by the testing authority, the designer, the client and the manufacturer.

## 8.5 Method of testing

### 8.5.1 General

The method by which the loading is to be applied and the positions at which the deflections are to be measured can only be decided by special reference to the particular structure, or part of a structure being tested, and to the particular loading condition, i.e. long-, medium-, short- or very short-term, being investigated.

Where loads of different durations act in combination, the shortest duration of loading may be used to determine a factor from Table 103, provided its induced stress is at least 50 % of the total.

The test loading should be both applied and resisted in a manner approximating reasonably to the actual service conditions. Lateral support to members should also represent but not exceed service conditions. Eccentricities, other than those necessary to simulate service conditions, should be avoided at points of loading and reaction, and care should be taken to ensure that no inadvertent restraints are present. Where it is clear that there is significant divergence from service conditions, either in loading or restraint, due allowance for it should be made by the supervising engineer. All reasonable combinations of dead, imposed and wind load should be considered when determining the worst loading conditions for test.

NOTE 1 For test purposes the worst loading condition is referred to as the design load.

Load-deflection readings should be taken and preferably plotted during a test.

NOTE 2 Load-deflection plots serve as a check against mistakes and show up irregularities in the behaviour of the structure to enable a particular weakness to be investigated as the test progresses.

When plotting load-deflection curves, allowance should be made for the self-weight of the structure and any ancillary loading equipment, and for any deflections recorded at the supports.

The accuracy of loading and of load measurements should be within ±3 %.

Modern test laboratories use computerized data acquisition equipment to monitor, record and plot the results continually. Whilst such equipment can, and when available should, be used to record all measurements described in this section, the test procedures are written assuming that such equipment is not available.

The structure should be tested as described in **8.5.2**, **8.5.3** and **8.5.4**.

### 8.5.2 Pre-load

A load equal to the dead load should be applied, maintained for a period of 30 min and then released. Deflections of the structure should be measured immediately before and immediately after the load has been released and again after a further 15 min. The last measurement taken serves as the datum for all subsequent deflection measurements in the deflection and strength tests.

Where camber is provided it should be measured relative to the support points after the release of all loads other than self-weight and loading equipment and immediately before the start of the deflection test.

### 8.5.3 Deflection test

Immediately following the pre-load test, the dead load should be applied again and maintained for 15 min. The additional load should be applied, either at a continuous rate or in equal increments with equal time between increments, until the design load is reached. The rate of loading should be such that the time taken to reach the design load from zero load is not less than 30 min and not more than 45 min. The design load should be maintained for 24 h and then released.

Deflection readings should be taken at the following times:

a) 15 min after application of the dead load;

b) 15 min after application of the design load;

c) at sufficient intervals throughout the 24 h period under the design load to enable a deflection-time curve to be plotted;

d) immediately before release of the load at the end of the 24 h period;

e) immediately after release of the load at the end of the 24 h period;

f) 15 min after release of the load.

### 8.5.4 Strength test for timber and/or plywood structures

Within 1 h of completing the preceding deflection test, the design load should be applied again in the same manner and at the same rate as for the deflection test.

When more than one structure of a particular design is being tested, the load should be increased to a value of 1.25 times the design load multiplied by the relevant value of $K_{85}$ from Table 103, or until failure occurs. The rate of loading for this additional load should be the same as that used between the dead and design loads, i.e. using the same increments of load and time.

Where only one structure of a particular design is being tested (see **8.1**), the load should be increased to a value of 1.25 times the design load multiplied by the relevant value of $K_{85}$ from Table 103, and maintained for 15 min. The rate of loading for this additional load should be the same as that used between the dead and design loads, i.e. using the same increments of load and time.

NOTE 1 At the end of the loading period, and at the discretion of the supervising engineer, the load may be increased until failure occurs.

NOTE 2 Deflection readings during the strength test may be made at the discretion of the supervising engineer.

At the end of the strength test, the maximum load and the moisture content of the timber should be recorded. When the structure is tested to failure, the moisture content recorded should be at the points of failure.

**Table 103 — Modification factors, $K_{85}$, for strength tests**

| Duration of loading | Load test on structure or component | Design by testing of roof and floor decking |
|---|---|---|
| Long-term (e.g. dead + permanent imposed [a]) | 2.00 | $K_{85} = 1.35\ \gamma_M k_{mod,test}/k_{mod,design}$<br>where<br>$\gamma_M$ = 1.2 for plywood<br>$\gamma_M$ = 1.3 for panels other than plywood<br>$k_{mod,test}$ is the modification factor for test load duration (see Table 57)<br>$k_{mod,design}$ is the modification factor for design load duration (see Table 57) |
| Medium-term (e.g. dead + snow, dead + temporary imposed) | 1.79 | |
| Short-term (e.g. dead + imposed + wind [b], dead + imposed + snow + wind [b]) | 1.52 | |
| Very short-term (e.g. dead + imposed + wind [c]) | 1.30 | |

NOTE For tests involving components subjected to different loading durations, the factor given above for the shortest duration of loading may be used, provided its induced stress is at least 50 % of the total.

[a] For floors, the uniformly distributed imposed load should be treated as long-term.
[b] For wind, short-term category applies to class C (15 s gust) or where the largest diagonal dimension of the loaded area *a*, as defined in BS 6399-2, exceeds 50 m.
[c] For wind, very short-term category applies to classes A and B (3 s or 5 s gust) or where the largest diagonal dimension of the loaded area *a*, as defined in BS 6399-2, does not exceed 50 m.

## 8.6 Acceptance

### 8.6.1 Deflection of timber and/or plywood structures

Specific recommendations as to maximum deflections cannot be given for all types of structure, and the deflections recorded during a test should be interpreted in relation to the functional requirements for a particular structure. However, at the end of the 24 h loading period, the maximum deflection recorded should not exceed 0.8 times the amount specified in the design. In addition, the rate of increase in deflection during the 24 h period should decrease.

### 8.6.2 Strength of timber and/or plywood structures

The design should be regarded as satisfactory if the lowest ultimate load recorded is at least $K_{73}$ times $K_{85}$ multiplied by the design load.

**Table 104 — Modification factor, $K_{73}$, for acceptance of structures**

| Number of similar structures tested | Value of $K_{73}$ |
|---|---|
| 1 | 1.25 |
| 2 | 1.15 |
| 3 | 1.08 |
| 4 | 1.03 |
| 5 or more | 1.00 |

Where only one structure is tested, the structure should be considered satisfactory if a load equal to 1.25 times $K_{85}$ multiplied by the design load is sustained without failure for 15 min.

### 8.6.3 Strength of partly or wholly particleboard structures

Where more than one structure of the same design is tested, the design should be regarded as satisfactory if the lowest ultimate load record is at least $K_{73}$ times $K_{85}$ multiplied by the maximum design load.

## 8.7 Test report

The report should contain, in addition to the test results, a clear statement of the conditions of testing, including the method of loading and of measuring deflection, together with any other relevant data. The type of failure and its position in the test structure should be recorded, together with the moisture content of the timber in the failed area.

The nature and size of defects in the timber or other materials which may have contributed to the failure should also be recorded. Photographs should be used where possible to illustrate the important points of the report.

Attention should be drawn to any possible defect in design or construction which may lead in turn to abnormal reduction in the strength or stiffness of the structure.

The report should also contain a clear statement as to whether or not the structure tested satisfies the acceptance conditions given in **8.6**.

## 8.8 Use of tested structures

A structure, or part of a structure which has been subjected to the deflection and strength test procedures given above should not be used further. A structure or part of a structure which has been subjected to a deflection test only, and which satisfies the deflection acceptance criteria given in **8.6**, may be considered satisfactory for further use subject to agreement between the supervising engineer, the client and the manufacturer.

However, where it is required to test a structure in service to estimate its load-carrying capacity, reference should be made to *Appraisal of existing structures* [22], published by the Institution of Structural Engineers.

## 8.9 Testing of roof and floor decking assemblies

### 8.9.1 Strength under concentrated load test

The design should be regarded as satisfactory if the lowest ultimate load recorded is as least $K_{73}K_{85}$ times the design load, where

| | |
|---|---|
| $\gamma_M$ | is the material partial factor (e.g. 1.2 for timber and plywood and 1.3 for other panel products); |
| $K_{85}$ | is a modification factor for strength tests (Table 103); |
| $K_{73}$ | is the modification factor for number of tests (Table 104). |

### 8.9.2 Serviceability under concentrated load test

The stiffness, $R_m$, in newtons per millimetre (N/mm) from one test or the average from more than one test, should satisfy the requirement given by:

$$R_m \geq \frac{F_d}{d_{perm}}\left(\frac{1 + k_{def,x}}{1 + k_{def,y}}\right)K_{73}$$

where

| | |
|---|---|
| $F_d$ | is the design load in newtons (N); |
| $d_{perm}$ | is the permissible deflection in millimetres (mm); |
| $k_{def,x}$ | is the modification factor for moduli of the material for the service condition of load duration (see Table 38 or Table 58). |
| $k_{def,y}$ | is the modification factor for moduli of the material for the duration of test taken as 5 min (see Table 38 or Table 58). |

### 8.9.3 Strength and serviceability under impact test

Five roof or floor assemblies of the same design should be tested in accordance with BS EN 1195, to satisfy the strength and serviceability requirements of BS EN 12871.

## Annex A (normative) Structural timbers

**Table A.1 — Names and densities of some structural softwoods**

| Standard name or species combination | Botanical species | Other common names or standard names of individual species | Source (see note) | Approximate mean density at a moisture content of 20 % kg/m³ |
|---|---|---|---|---|
| Parana pine | *Araucaria angustifolia* | | Brazil | 560 |
| Caribbean pitch pine | *Pinus caribaea* | longleaf pitch pine | Caribbean | 720 |
| | *Pinus oocarpa* | Nicaraguan pitch pine | | |
| | | Honduras pitch pine | | |
| western red cedar | *Thuja plicata* | British Columbia red cedar | Canada and USA | 380 |
| radiata pine | *Pinus radiata* | | New Zealand and Chile | 540 |
| redwood | *Pinus sylvestris* | | CNE Europe | 540 |
| whitewood | *Picea abies* | Baltic whitewood | CNE Europe | 510 |
| | *Abies alba* | | | |
| South African pine | *Pinus taeda* | | South Africa | 570 |
| | *Pinus elliottii* | | | |
| | *Pinus patula* | | | |
| Zimbabwean pine | *Pinus taeda* | | Zimbabwe | 570 |
| | *Pinus elliottii* | | | |
| | *Pinus patula* | | | |
| Sitka spruce | *Picea sitchensis* | | Canada | 430 |
| Douglas fir-larch | *Pseudotsuga menziesii* | Douglas fir | Canada and USA | 590 |
| | *Larix occidentalis* | western larch | | |
| hem-fir | *Tsuga heterophylla* | western hemlock | Canada | 470 |
| | *Abies amabilis* | amabilis fir | | |
| | *Abies grandis* | grand fir | | |
| hem-fir | *Tsuga heterophylla* | western hemlock | USA | 470 |
| | *Abies amabilis* | amabilis fir | | |
| | *Abies magnifica* | California red fir | | |
| | *Abies grandis* | grand fir | | |
| | *Abies procera* | noble fir | | |
| | *Abies concolor* | white fir | | |
| spruce-pine-fir | *Picea mariana* | black spruce | Canada and USA | 450 |
| | *Picea engelmannii* | Engelmann spruce | | |
| | *Picea rubens* | red spruce | | |
| | *Picea glauca* | white spruce | | |
| | *Pinus banksiana* | jack pine | | |
| | *Pinus contorta* | lodgepole pine | | |
| | *Pinus ponderosa* | ponderosa pine | | |
| | *Abies lasiocarpa* | alpine fir | | |

NOTE CNE Europe: Central, northern and eastern Europe.

**Table A.1 — Names and densities of some structural softwoods** *(continued)*

| Standard name or species combination | Botanical species | Other common names or standard names of individual species | Source (see note) | Approximate mean density at a moisture content of 20 % kg/m$^3$ |
|---|---|---|---|---|
| | *Abies balsamea* | balsam fir | | |
| southern pine | *Pinus palustris* | longleaf pine | USA | 690 |
| | *Pinus elliottii* | slash pine | | |
| | *Pinus echinata* | shortleaf pine | | |
| | *Pinus taeda* | loblolly pine | | |
| western white woods | *Pinus engelmannii* | Engelmann spruce | USA | 430 |
| | *Pinus monticola* | western white pine | | |
| | *Pinus contorta* | lodgepole pine | | |
| | *Pinus ponderosa* | ponderosa pine | | |
| | *Pinus lambertiana* | sugar pine | | |
| | *Abies lasiocarpa* | alpine fir | | |
| | *Abies balsamea* | balsam fir | | |
| | *Tsuga mertensiana* | mountain hemlock | | |
| Douglas fir-larch | *Psuedotsuga menziesii* | | UK | 560 |
| | *Larix eurolepis* | hybrid larch | UK | 520 |
| | *Larix decidua* | larch | | 610 |
| | *Larix kaempferi* | larch | | 580 |
| British pine | *Pinus nigra var. maritima* | Corsican pine | UK and Ireland | 510 |
| | *Pinus sylvestris* | Scots pine | | 540 |
| British spruce | *Picea abies* | Norway spruce | UK and Ireland | 450 |
| | *Picea sitchensis* | Sitka spruce | | 450 |

NOTE CNE Europe: Central, northern and eastern Europe.

**Table A.2 — Names and densities of some structural hardwoods**

| Standard name or species combination | Botanical species | Other common names or standard names of individual species | Source | Approximate mean density at a moisture content of 20 % kg/m³ |
|---|---|---|---|---|
| a) Tropical | | | | |
| balau [a] | *Shorea* spp. including: | | South east Asia | 1 010 |
| | *Shorea glauca* | | | |
| | *Shorea maxwelliana* | | | |
| ekki | *Lophira alata* | | West Africa | 1 100 |
| greenheart | *Ocotea rodiaei* | | South America | 1 060 |
| iroko | *Milicia excelsa* | mvule | Africa | 690 |
| | *Milicia regia* | | | |
| jarrah | *Eucalyptus marginata* | | Australia | 840 |
| kapur | *Dryobalanops aromatica* | | South east Asia | 810 |
| | *Dryobalanops oblongifolia* | | | |
| karri | *Eucalyptus diversicolor* | | Australia | 930 |
| kempas | *Koompassia malaccensis* | impas | South east Asia | 900 |
| keruing | *Dipterocarpus* spp. including: | Malaysian gurjun | South east Asia | 760 |
| | *Dipterocarpus cornutus* | | | |
| | *Dipterocarpus costulatus* | | | |
| | *Dipterocarpus crinitus* | kusia | | |
| | *Dipterocarpus sublamellatus* | | | |
| merbau | *Intsia bijuga* | | South east Asia | 890 |
| | *Intsia palembanica* | | | |
| opepe | *Nauclea diderrichii* | kusia | Africa | 780 |
| teak | *Tectona grandis* | | South east Asia and Africa | 680 |
| b) Temperate | | | | |
| oak | *Quercus robur* or *Quercus petraea* | English oak | UK | 600 |
| sweet chestnut | *Castanea sativa* | | Europe | 450 |

[a] Red balau (principally *Shorea guiso, Shorea kunstleri*) is not included.

## Annex B (normative)
## Modification factor for compression members

The value of the modification factor, $K_{12}$, for compression members with slenderness ratios equal to or greater than 5 is given by the equation:

$$K_{12} = \left\{\frac{1}{2} + \frac{(1+\eta)\,\pi^2 E}{2N\lambda^2\sigma_c}\right\} - \left[\left\{\frac{1}{2} + \frac{(1+\eta)\,\pi^2 E}{2N\lambda^2\sigma_c}\right\}^2 - \frac{\pi^2 E}{N\lambda^2\sigma_c}\right]^{1/2}$$

where

$\sigma_c$ is the compression parallel to the grain stress for the particular conditions of loading (see **2.11.5**);

$E$ is the appropriate modulus of elasticity for the particular exposure condition (see **2.6.2** and **2.11.5**);

$\lambda$ is the slenderness ratio, i.e. the effective column length divided by the radius of gyration ($L_e/i$);

$\eta$ is the eccentricity factor (taken as 0.0052 in deriving the values given in Table 22);

$N$ is the reduction factor used to derive grade compression stresses and moduli of elasticity and, in this case, has the value 1.5.

For the specific purpose of calculating $K_{12}$, the minimum value of $E$ (modified if applicable by $K_9$ or $K_{28}$, see **2.11.5**) should be used and $\sigma_c$ should not include any allowance for load sharing.

For compression members acting alone, the permissible stress is:

$\sigma_{c,adm} = K_{12}\sigma_c$

For compression members in load-sharing systems (see **2.9**) the permissible stress is:

$\sigma_{c,adm} = 1.1K_{12}\sigma_c$

## Annex C (normative)
## Efficiency ratings of glued end joints in softwoods

Table C.1 lists efficiency ratings for some common profiles of finger joints manufactured in accordance with BS EN 385. The efficiencies given in Table C.1 apply only to joints with profiles visible either on the face or edge of rectangular sections, provided that at least four complete fingers are present.

**Table C.1 — Efficiency ratings of some finger profiles**

| Finger profiles | | | Efficiency rating in bending and tension parallel to grain | Efficiency rating in compression parallel to grain |
|---|---|---|---|---|
| Length<br>mm | Pitch<br>mm | Tip width<br>mm | % | % |
| 55 | 12.5 | 1.5 | 75 | 88 |
| 50 | 12.0 | 2.0 | 75 | 83 |
| 40 | 9.0 | 1.0 | 65 | 89 |
| 32 | 6.2 | 0.5 | 75 | 92 |
| 30 | 6.5 | 1.5 | 55 | 77 |
| 30 | 11.0 | 2.7 | 50 | 75 |
| 20 | 6.2 | 1.0 | 65 | 84 |
| 15 | 3.8 | 0.5 | 75 | 87 |
| 12.5 | 4.0 | 0.7 | 65 | 82 |
| 12.5 | 3.0 | 0.5 | 65 | 83 |
| 10 | 3.7 | 0.6 | 65 | 84 |
| 10 | 3.8 | 0.6 | 65 | 84 |
| 7.5 | 2.5 | 0.2 | 65 | 92 |

## Annex D (informative)
## Species of timber used in the manufacture of plywood

### D.1 American plywood

The species of timber which may be used to manufacture plywood in accordance with US Voluntary Product Standard PS 1-95 [10] are classified into five groups based on modulus of elasticity in bending and important strength properties. The groups relevant to the American plywoods given in BS 5268-2 are groups 1 and 2, the compositions of which are listed in Table D.1.

Plywood grades C-D, C-D (plugged) and Underlayment Exposure 1 consist of Group 1 face and back plies and Group 1 or 2 inner plies.

Plywood grades C-C, C-C (plugged) and Underlayment Exterior consist of Group 1 plies throughout.

### D.2 Canadian plywood

The species of timber which may be used to manufacture plywood to Canadian Plywood Manufacturing Standards, CSA 0121 — M 1978 [8] and CSA 0151 — M 1978 [9], and which are relevant to the COFI plywoods given in BS 5268-2 are listed in Table D.2.

### D.3 Finnish plywood

The species of timber which may be used to manufacture plywood in accordance with the following Finnish and British Standards and which are relevant to Finnish plywoods given in BS 5268-2 are listed in Table D.3: SFS 2412 [12], SFS 2413 [13], SFS 4091 [14], SFS 4092 [15], BS EN 310, BS EN 314, BS EN 315, BS EN 322, BS EN 323 and BS EN 324.

### D.4 Swedish plywood

The species of timber which may be used in Swedish manufactured P30 plywood to Swedish Standard SBN 1975:5 [16] which is relevant to the Swedish plywood given in BS 5268-2, are redwood and whitewood as given in Table D.4.

**Table D.1 — Species used in American C-D, C-D (plugged), C-C, C-C (plugged), Underlayment Exposure 1 or Exterior plywood**

| Group 1 | Group 2 |
|---|---|
| apitong [a b] | cedar, Port Orford |
| beech, American | cypress |
| birch | Douglas fir No. 2 [c] |
| sweet | fir |
| yellow | balsam fir |
| Douglas fir No. 1 [c] | California red |
| kapur [a] | grand |
| keruing [a b] | noble |
| larch, western | pacific silver |
| maple, sugar | white |
| pine | hemlock, western |
| Caribbean | lauan |
| ocote | almon |
| pine, southern | bagtikan |
| loblolly | mayapis |
| longleaf | red lauan |
| shortleaf | tangile |
| slash | white lauan |
| tanoak | maple, black |
| | mengkulang [a] |
| | meranti, red [a d] |
| | mersawa [a] |
| | pine |
| | pond |
| | red |
| | Virginia |
| | western white |
| | spruce |
| | black |
| | red |
| | Sitka |
| | sweet gum |
| | tamarack |
| | yellow poplar |

[a] Each of these names represents a trade group of woods consisting of a number of closely related species.
[b] Species from the genus *Dipterocarpus* are marked collectively; apitong if originating in the Philippines; keruing if originating in Malaysia or Indonesia.
[c] Douglas fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian Provinces of Alberta and British Columbia are classed as Douglas fir No. 1. Douglas fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico are classed as Douglas fir No. 2.
[d] Red meranti are limited to species having a relative density of 0.41 or more based on green volume and oven dry mass.

**Table D.2 — Species used in Canadian plywood**

| Faces and backs [a] | Inner plies |
|---|---|
| CANPLY exterior Douglas fir plywood | |
| Douglas fir | Douglas fir<br>western hemlock<br>true fir<br>Sitka spruce<br>western white spruce<br>western larch<br>western white pine<br>ponderosa pine<br>lodgepole pine |
| CANPLY exterior Canadian softwood plywood | |
| western hemlock<br>true fir<br>Sitka spruce<br>western white spruce<br>lodgepole pine | Douglas fir<br>western hemlock<br>true fir<br>Sitka spruce<br>western white spruce<br>western larch<br>western white pine<br>ponderosa pine<br>lodgepole pine |

[a] Backs of 6 mm, 8 mm, 11 mm and 14 mm good one side grade may be western hemlock, true fir, Sitka spruce, western white spruce, western larch or lodgepole pine.

**Table D.3 — Species used in Finnish plywood**

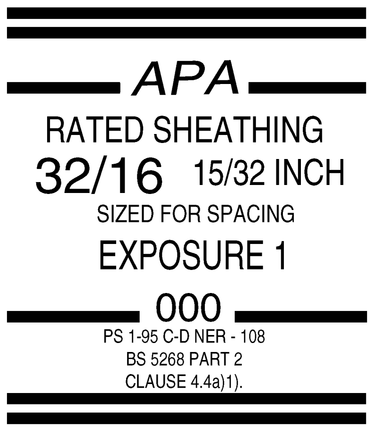
| Finnish birch plywood | Finnish birch-faced plywood | Finnish conifer plywood |
|---|---|---|
| European white birch | European white birch<br><br>European spruce | European spruce<br><br>redwood |

**Table D.4 — Species used in Swedish softwood plywood**

| Swedish softwood plywood |
|---|
| European spruce<br>redwood |

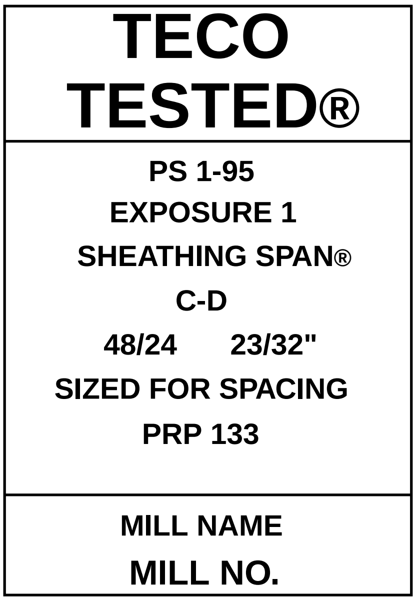
## Annex E (informative)
## Grade marks for plywood

Grade marks for plywood from various sources are shown in Figure E.1, Figure E.2, Figure E.3 and Figure E.4. It should be noted that the representation of the marks is intended to be illustrative rather than comprehensive.




Refer to **4.4**a)1).

a) APA grade mark

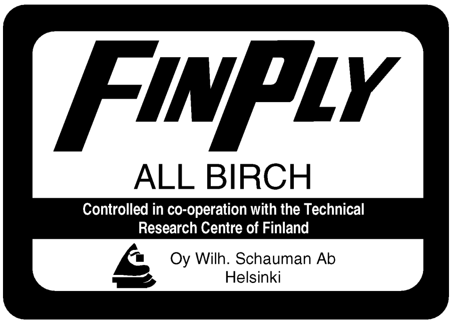



b) TECO grade mark

**Figure E.1 — American construction and industrial plywoods**

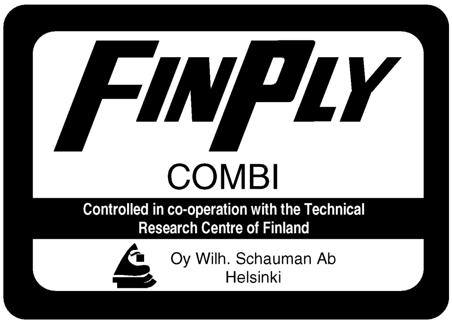

Refer to **4.4**b).

**Figure E.2 — Canadian Douglas fir and softwood plywoods**



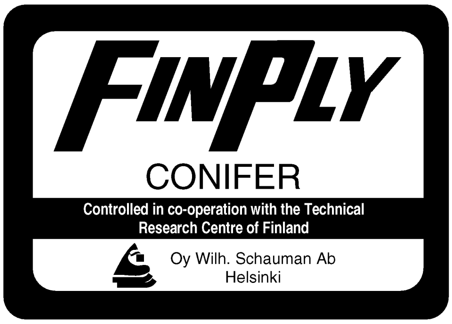

Refer to 4.4c) 1).

a)




Refer to clause 4.4c) 3).

b)




Refer to 4.4c) 2).

c)

**Figure E.3 — Finnish birch, birch-faced and conifer plywoods**

**CC 12,0 EN 636-3** **SP P30**
**1999-09-25 TVx** **3032/78**

Refer to 4.4d).

**Figure E.4 — Swedish softwood plywood**

## Annex F *Text deleted.*

## Annex G (informative) Derivation of the basic lateral load-carrying capacities referred to in section 6

### G.1 General

All load-carrying capacities calculated using the equations in this annex are subject to the design rules given in section **6**.

The basic loads for particleboard-to-timber joints in Table 64 were calculated directly from test results; design equations cannot therefore be given.

### G.2 Nailed and screwed joints

The basic loads, in newtons for nailed joints with timber, plywood and tempered hardboard members, and screwed joints with timber and plywood members, are calculated from the following equations taken from DD ENV 1995-1-1:1994 (Eurocode 5):

$$F = \frac{1}{F_{\mathrm{d}}K_{\mathrm{d}}} \times \text{minimum of} \begin{cases} f_{\mathrm{h,1,d}}t_1 d & \text{(G.1)} \\ f_{\mathrm{h,1d}}t_2 d\,\beta & \text{(G.2)} \\ K_{2\mathrm{b}}\dfrac{f_{\mathrm{h,1,d}}t_1 d}{1+\beta}\left(\left[\beta + 2\beta^2\left\{1+\dfrac{t_2}{t_1}+\left(\dfrac{t_2}{t_1}\right)^2\right\}+\beta^3\left(\dfrac{t_2}{t_1}\right)^2\right]^{1/2} - \beta\left(1+\dfrac{t_1}{t_2}\right)\right) & \text{(G.3)} \\ 1.1\,\dfrac{f_{\mathrm{h,1,d}}t_1 d}{2+\beta}\left[\left\{2\beta\,(1+\beta)+\dfrac{4\beta(2+\beta)M_{\mathrm{y,d}}}{f_{\mathrm{h,1,d}}d{t_1}^2}\right\}^{1/2} - \beta\right] & \text{(G.4)} \\ 1.1\,\dfrac{f_{\mathrm{h,1,d}}t_2 d}{1+2\beta}\left[\left\{2\beta^2\,(1+\beta)+\dfrac{4\beta(1+2\beta)M_{\mathrm{y,d}}}{f_{\mathrm{h,1,d}}d{t_2}^2}\right\}^{1/2} - \beta\right] & \text{(G.5)} \\ 1.1\sqrt{\dfrac{2\beta}{1+\beta}}\sqrt{2M_{\mathrm{y,d}}f_{\mathrm{h,1,d}}d} & \text{(G.6)} \end{cases}$$

where

| | |
|---|---|
| $F_d$ | = 1.4; |
| $K_d$ | = 1.12, for timber-to-timber and plywood-to-timber joints; |
| | = 1.25, for timber-to-tempered hardboard joints; |
| $K_{2b}$ | = 1.00, for nailed and screwed joints; |
| $t_1$ | is the thickness of the headside member (in mm) (see Figure G.1); |
| $t_2$ | is the pointside penetration of the fastener (in mm); |
| $d$ | is the diameter of a round nail or the diameter of the smooth shank of a screw (in mm); |
| $M_{y,d}$ | is the fastener yield moment (in N·mm); |
| | = $164d^{2.6}$, for nails; |
| | = $114d^{2.6}$, for screws; |
| $f_{h,1,d}$ ($f_{h,2,d}$) | is the embedding strength in $t_1$ or $t_2$ (in N/mm²); |
| | = $0.05\rho_k d^{-0.3}$, for unpre-drilled nails in timber; |
| | = $0.05(1 - 0.01d)\rho_k$, for pre-drilled nails or screws up to 8 mm diameter in timber; |
| | = $0.038(1 - 0.01d)\rho_k$, for pre-drilled nails or screws greater than 8 mm diameter in timber; |
| | = $0.068\rho_k d^{-0.3}$, for nails and screws in plywood; |
| | = $10.38d^{-0.3}t_1^{0.6}$, for nails in tempered hardboard; |
| $\beta$ | = $f_{h,2,d}/f_{h,1,d}$; |
| $\rho_k$ | is the characteristic density (in kg/m³) at 12 % moisture content (see Table G.1 and Table G.2). |

NOTE The values for nailed timber-to-timber joints (Table 61) were calculated with $t_1$ and $t_2$ equal to the standard penetration; for nailed plywood-to-timber joints (Table 63) and for nailed tempered hardboard-to-timber joints (Table 64) $t_1$ and $t_2$ were equal to the board thickness and to nail length less the board thickness respectively. For screwed timber-to-timber joints (Table 66) $t_1$ and $t_2$ were equal to the standard headside thickness and twice the standard headside thickness respectively; for screwed plywood-to-timber joints (Table 68) $t_1$ and $t_2$ were equal to the board thickness and to screw length less the board thickness respectively.

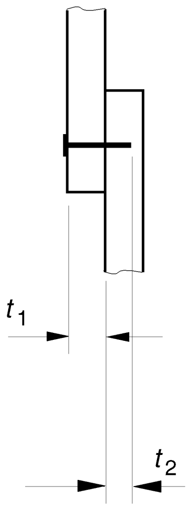



Diagram indicating the dimensions
$t_1$ and $t_2$ of nailed/screwed joints

**Figure G.1 — Diagram indicating the dimensions $t_1$ and $t_2$ of nailed/screwed joints**

**Table G.1 — Characteristic density of timber at 12 % moisture content**

| **Strength class** | **Characteristic density $\rho_k$** kg/m$^3$ |
|---|---|
| C14 | 290 |
| C16/18/20/TR20/C22 | 310 |
| C24 | 350 |
| TR26/C27/30/35/40 | 370 |
| D30/35/40 | 530 |
| D50/60/70 | 650 |

**Table G.2 — Characteristic density of plywood at 12 % moisture content**

| **Plywood thickness** mm | **Characteristic density $\rho_k$** kg/m$^3$ | |
|---|---|---|
| | **Plywood group I** | **Plywood group II** |
| 6 | 527 | 641 |
| 9 | 505 | 641 |
| 12 | 505 | 628 |
| 15 | 505 | 614 |
| 18 | 505 | 599 |
| 21 | 505 | 593 |
| 29 | 505 | 548 |

### G.3 Bolted and dowelled joints

The basic loads, in kilonewtons, for two-member joints are calculated by inserting the following values in equations G.1 to G.6:

| | |
|---|---|
| $F_d$ | = 1 350, for long-term load; |
| | = 1 400 for medium- and short-/very short-term load; |
| $K_d$ | = 1.00; |
| $K_{2b}$ | = 1.33 for bolted joints; |
| | = 1.00 for dowelled joints; |
| $t_1$ and $t_2$ | are the member thicknesses (in mm) (see Figure G.2); |
| $d$ | is the bolt or dowel diameter (in mm); |
| $M_{y,d}$ | is the fastener yield moment (in N·mm); |
| | $= 0.12 f_y d^3$; |
| | where $f_y = 400$ N/mm² for grade 4.6 bolts or dowels. |

For fastener loading at any angle $\alpha$ to the grain (with $\alpha$ in the range $0° \leq \alpha \leq 90$), the embedding strength is:

$$f_{h,\alpha,d} = \frac{f_{h,0,d}}{K_{90}\sin^2\alpha + \cos^2\alpha}$$

where the embedding strength $f_{h,0,d} = 0.038\,(1 - 0.01d)\,\rho_k\,K_\alpha$ for long-terms loads

$= 0.050\,(1 - 0.01d)\,\rho_k\,K_\alpha$ for medium-term loads

$= 0.057\,(1 - 0.01d)\,\rho_k\,K_\alpha$ for short-/very short-term loads

with $\rho_k$ the characteristic density of each member (in kg/m³) at 12 % moisture content (see Table G.1 and Table G.2):

and $K_a = \sqrt{\dfrac{a_{||}}{(4 + 3\cos\alpha)d}}$

where $a_{\|}$ is the spacing parallel to the grain (with $a_{\|}$ in the range $4d \leq a_{\|} \leq 7d$)

and

$K_{90} = 1.35 + 0.015d$ for softwoods;

$= 0.90 + 0.015d$ for hardwood.

The single shear load perpendicular to the grain should not exceed the corresponding single shear load parallel to the grain.

The embedding strengths in members 1 and 2 ($f_{h,1,d}$ and $f_{h,2,d}$ respectively) are derived using the values for $\rho_k$, $\alpha$, duration of load, fastener spacing and timber species group relevant for each member:

$\beta = f_{h,2,d}/f_{h,1,d}$

NOTE 1 The values in Table 69, Table 70, Table 71, Table 72, Table 73 and Table 74 for loading parallel to the grain were calculated with $\alpha_{\|} = 4d$, $\beta = 1.00$ and $t_1 = t_2$; for loading perpendicular to the grain $\alpha = 90°$ and $f_{h,1,d} = f_{h,2,d} = f_{h,90,d}$.

For three member joints, the basic load per shear plane in kilonewtons is calculated by inserting the values given above into the following equations from DD ENV 1995-1-1:

$$F = \frac{1}{F_d K_d} \times \text{minimum of} \begin{cases} f_{h,1,d} t_1 d & \text{(G.7)} \\ 0.5 f_{h,1,d} t_2 d \beta & \text{(G.8)} \\ 1.1 \dfrac{f_{h,1,d} t_1 d}{2 + \beta} \left[ \left\{ 2\beta (1 + \beta) + \dfrac{4\beta(2 + \beta) M_{y,d}}{f_{h,1,d} d t_1^{2}} \right\}^{1/2} - \beta \right] & \text{(G.9)} \\ 1.1 \sqrt{\dfrac{2\beta}{1 + \beta}} \sqrt{2 M_{y,d} f_{h,1,d} d} & \text{(G.10)} \end{cases}$$

where

$t_1$ is the smaller outer member thickness (in mm);

$t_2$ is the inner member thickness (in mm) (in Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80, $t_1 = 0.5t_2$).

NOTE 2 The values in Table 75, Table 76, Table 77, Table 78, Table 79 and Table 80 for loading parallel to the grain were calculated with $\alpha_{\parallel} = 4d$, $\beta = 1.00$ and $t_1 = 0.5\,t_2$; for loading perpendicular to the grain, $\alpha = 90°$ and $f_{h,1,d} = f_{h,2,d} = f_{h,90,d}$.

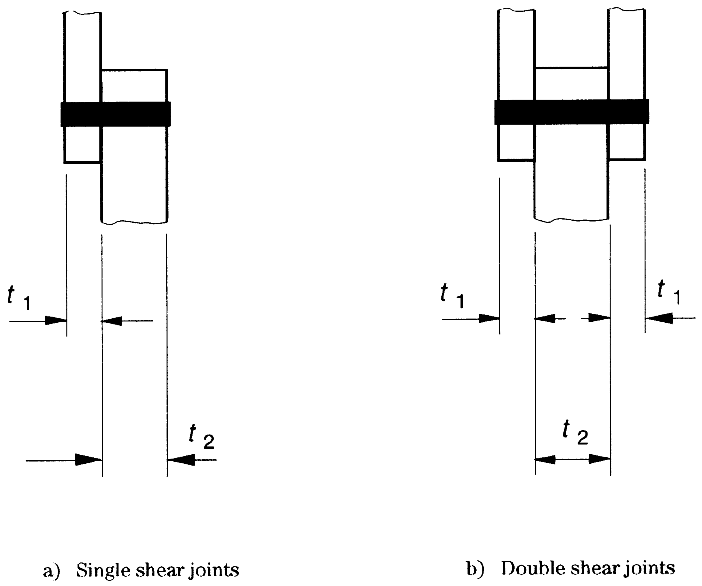



**Figure G.2 — Bolted/dowelled joints**

## G.4 Connectored joints

The basic loads for toothed-plate, split-ring and shear-plate connectored joints given in Table 86, Table 94 and Table 98, respectively, were calculated directly from test results; design equations cannot therefore be given.

## Annex H (normative) Moisture content determination by oven dry method

A test piece free from knots should be cut from the timber not closer to an end than 250 mm. It should have a length along the grain of 25 mm ± 5 mm, and should include the full cross-section of the timber.

The test-piece should be weighed to an accuracy of 0.5 % and then dried to constant mass in a vented oven at a temperature of 103 °C ± 2 °C. Constant mass is considered to be reached if the loss in mass between two successive weighings carried out at an interval of 6 h is not greater than 0.5 % of the mass of the test piece.

After cooling, which should be sufficiently quick to avoid an increase in moisture content, the test piece should again be weighed to an accuracy of 0.5 %.

The moisture content, $\omega$, of the test piece, expressed as a percentage by mass, should be calculated to an accuracy of 1 % from the equation:

$$\omega = 100\,(m_1 - m_2)/m_2$$

where

$m_1$ is the mass of the test piece before drying in grams (g);

$m_2$ is the mass of the test piece after drying in grams (g).

## Annex J *Text deleted.*

## Annex K (normative) Deflection and stiffness

The dimensions of flexural members should restrict deflection within limits appropriate to the type of structure, having regard to the possibility of damage to surfacing materials, ceilings, partitions and finishings, and to the functional needs as well as aesthetics.

In addition to the deflection due to bending, the shear deflection may be significant and should be taken into account.

For the analysis of statically indeterminate structures only the flexural stiffness of the members need be considered.

The deflections of timber members should be calculated using the mean modulus of elasticity for the strength class or species grade.

The deflection of load-sharing systems, built-up beams, trimmer joints and lintels should be calculated using **2.9**, **2.10.10** and **2.10.11** respectively.

Subject to consideration being given to the effect of excessive deformation, members may be pre-cambered to account for the deflection under full dead or permanent load.

For most general purposes, the recommendations of Annex K may be assumed to be followed if the following conditions are met:

$$u_{\mathrm{instQ},1} + \sum_{j>1} u_{\mathrm{instQ},j}\Psi_{0,j} \le \frac{s}{350} \qquad \text{(K.1)}$$

$$u_{\mathrm{finG}} + u_{\mathrm{finQ}} - u_{\mathrm{c}} \le \frac{s}{200} \qquad \text{(K.2)}$$

and for domestic floor joists

$$\sum_{i>0} u_{\mathrm{instG},i} + \sum_{j>0} u_{\mathrm{instQ},j} \le 14\ \mathrm{mm} \qquad \text{(K.3)}$$

NOTE The 14 mm deflection limit is to avoid undue vibration under moving or impact loading. An alternative procedure for domestic floor joists, and for other types of loading where the designer considers vibration should be taken into account, is given in Guidance document 6 (GD6), *Vibration in timber floors*, published by TRADA Technology, High Wycombe [23].

where

- $s$ is the span;
- $u_{\mathrm{instG},i}$ is the instantaneous deflection in millimetres (mm) under dead load $i$;
- $u_{\mathrm{instQ},j}$ is the instantaneous deflection in millimetres (mm) under imposed load $j$;
- $u_{\mathrm{c}}$ is the in-built camber in millimetres (mm);
- $u_{\mathrm{finG}}$ is given by $\sum_{i>0} u_{\mathrm{instG},i}(1 + k_{\mathrm{def}})$;
- $u_{\mathrm{finQ}}$ is given by $u_{\mathrm{instG},i}(1 + \Psi_{2,1}k_{\mathrm{def}}) + \sum_{i>1} u_{\mathrm{instQ},j}(\Psi_{0,j} + \Psi_{2,j}k_{\mathrm{def}})$;
- $\Psi_{0,j}$ is the load combination factor (see Table K.1);
- $\Psi_{2,i}$ is the load combination factor (see Table K.1);
- $k_{\mathrm{def}}$ is the load factor for creep deflection (see Table K.2).

**Table K.1 — Load combination factors**

| Imposed load category | $\Psi_0$ | $\Psi_2$ |
|---|---|---|
| Residential, institutional, educational | 0.7 | 0.3 |
| Offices and banks | 0.7 | 0.3 |
| Public assembly | 0.7 | 0.6 |
| Retail | 0.7 | 0.6 |
| Storage | 1.0 | 0.8 |
| Snow loads | 0.6 | 0.0 |
| Wind loads | 0.6 | 0.0 |

**Table K.2 — Deflection factors for solid timber and glulam, $k_{\mathrm{def}}$**

| | Service class | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Long-term | 0.60 | 0.80 | 2.00 |
| Medium-term | 0.25 | 0.25 | 0.75 |
| Short- and very short-term | 0.00 | 0.00 | 0.00 |

NOTE Where solid timber is wet when installed (i.e. equivalent to the service class 3 condition) and is likely to dry out under load to the dry condition (i.e. equivalent to the service class 2 or service class 1 condition), the service class 3 value for $k_{\mathrm{def}}$ should be increased by 1.0.

## Annex L (informative) *K* factors

Table L.1 gives a summary of modification factors, *K*.

**Table L.1 — Modification factors, *K***

| Symbol | Description | Reference in BS 5268-2:2002 |
|---|---|---|
| $K_1$ | Not used | |
| $K_2$ | Converts service classes 1 and 2 strength values to service class 3 | **2.6.2**, Table 16 |
| $K_3$ | Duration of load factor for timber and glulam | **2.8**, Table 17 |
| $K_4$ | Bearing stress factor | **2.10.2**, Table 18 |
| $K_5$ | Shear factor at notched end | **2.10.4** |
| $K_6$ | Form factor | **2.10.5** |
| $K_7$ | Depth factor | **2.10.6** |
| $K_8$ | Load sharing factor | **2.10.11** |
| $K_9$ | Modification factor for minimum E | **2.10.11**, Table 20 |
| $K_{10}$ | Not used | |
| $K_{11}$ | Not used | |
| $K_{12}$ | Factor for compression members | **2.11.5**, Table 22 |
| $K_{13}$ | Effective length of spaced columns | **2.11.10**, Table 23 |
| $K_{14}$ | Width factor for tension members | **2.12.2** |
| $K_{15}$ to $K_{20}$ | Factors for single grade horizontally glued laminated beams | **3.2**, Table 24 |
| $K_{21}$ | Not used | |
| $K_{22}$ | Not used | |
| $K_{23}$ | Not used | |
| $K_{24}$ | Not used | |
| $K_{25}$ | Not used | |
| $K_{26}$ | Not used | |
| $K_{27}$ to $K_{29}$ | Factors for vertically glued laminated members | **3.3**, Table 25 |
| $K_{30}$ to $K_{32}$ | Glued end joints in horizontally glued laminated members | **3.4**, Table 26 |
| $K_{33}$ | Modification factor for grade strengths in curved glulam | **3.5.3.2** |
| $K_{34}$ | Factor for bending stress in curved glulam | **3.5.3.2** |
| $K_{35}$ | Factor for bending stress in pitched cambered glulam beams | **3.5.4.2** |
| $K_{36}$ | Duration of load and service class factor for plywood | **4.5**, Table 39 |
| $K_{37}$ | Rolling shear stress concentration factor for plywood | **4.7** |
| $K_{38}$ | Not used | |
| $K_{39}$ | Not used | |
| $K_{40}$ | Not used | |
| $K_{41}$ | Not used | |
| $K_{42}$ | Not used | |
| $K_{43}$ | End grain factor for nails and screws | **6.4.4.1**, **6.5.4.1** |
| $K_{44}$ | Factor for lateral load on improved nails | **6.4.4.4** |
| $K_{45}$ | Factor for withdrawal load of improved nails | **6.4.4.4** |

**Table L.1 — Modification factors, $K$ (*continued*)**

| Symbol | Description | Reference in BS 5268-2:2002 |
|---|---|---|
| $K_{46}$ | Factor for steel plate/timber joints with nails, screws and bolts/dowels | **6.4.5.2**, **6.5.5.2**, **6.6.5.2**, **6.6.7.1** |
| $K_{47}$ | Not used | |
| $K_{48}$ | Duration of load factor for nailed timber joints | **6.4.9** |
| $K_{49}$ | Service class modification factor for nailed timber joints | **6.4.9** |
| $K_{50}$ | Factor for number of nails in timber joints | **6.4.9** |
| $K_{51}$ | Not used | |
| $K_{52}$ | Duration of load factor for screwed timber joints | **6.5.7** |
| $K_{53}$ | Service class modification factor for screwed timber joints | **6.5.7** |
| $K_{54}$ | Factor for number of screws in timber joints | **6.5.7** |
| $K_{55}$ | Not used | |
| $K_{56}$ | Service class modification factor for bolted/dowelled timber joints | **6.6.6** |
| $K_{57}$ | Factor for number of bolts/dowels in a timber joint | **6.6.6** |
| $K_{58}$ | Duration of load factor for tooth plate connectored joints | **6.7.6** |
| $K_{59}$ | Service class modification factor for tooth plate connectored joints | **6.7.6** |
| $K_{60}$ | End, edge and spacing factor for tooth plate connectored joints | **6.7.6** |
| $K_{61}$ | Factor for number of tooth plate connectors in a joint | **6.7.6** |
| $K_{62}$ | Duration of load factor for split ring connectored joints | **6.8.5** |
| $K_{63}$ | Service class modification factor for split ring connectored joints | **6.8.5** |
| $K_{64}$ | End, edge and spacing factor for split ring connectored joints | **6.8.5** |
| $K_{65}$ | Factor for number of split ring connectors in a joint | **6.8.5** |
| $K_{66}$ | Duration of load factor for shear plate connectored joints | **6.9.6** |
| $K_{67}$ | Service class modification factor for shear plate connectored joints | **6.9.6** |
| $K_{68}$ | End, edge and spacing factor for shear plate connectored joints | **6.9.6** |
| $K_{69}$ | Factor for number of shear plate connectors in a joint | **6.9.6** |
| $K_{70}$ | Shear stress factor for nailed/stapled glue joints | **6.10.1.3**, **6.10.1.4**, **6.10.1.5** |
| $K_{71}$ | Not used | |
| $K_{72}$ | Not used | |
| $K_{73}$ | Factor for the number of similar structures tested | **8.6.2**, **8.6.3**, **8.9.1**, Table 104 |
| $K_{74}$ | Not used | |
| $K_{75}$ | Not used | |
| $K_{76}$ | Not used | |
| $K_{77}$ | Not used | |
| $K_{78}$ | Not used | |
| $K_{79}$ | Not used | |
| $K_{80}$ | Not used | |
| $K_{81}$ | Not used | |
| $K_{82}$ | Not used | |

**Table L.1 — Modification factors, $K$ (*concluded*)**

| Symbol | Description | Reference in BS 5268-2:2002 |
|---|---|---|
| $K_{83}$ | Not used | |
| $K_{84}$ | Not used | |
| $K_{85}$ | Modification factor for duration of load in strength test | **8.5.4**, **8.6.2**, **8.6.3**, Table 103 |
| $K_{86}$ | Not used | |
| $K_{87}$ | Not used | |
| $K_{88}$ | Not used | |
| $K_{89}$ | Not used | |
| $K_{90}$ | Perpendicular to grain factor for bolts and dowels | **G.3** |
| $K_{\alpha}$ | Spacing factor for bolts and dowels | **G.3** |
| $K_{d}$ | Modification factor for nails, screws, bolts and dowels | **G.2**, **G.3** |
| $K_{dowel}$ | Reduction factor for dowels | **6.6.7.4** |
| $K_{ser}$ | Fastener slip moduli | **6.2**, Table 59 |
| $K_{c}$ | End distance factor for toothed-plate connectors | **6.7.6**, Table 87, Table 88 |
| $K_{s}$ | Spacing factor for toothed-plate connectors | **6.7.6**, Table 85 |
| $K_{C}$ | End distance factor for split rings and dowels | **6.8.5**, Table 95 |
| $K_{D}$ | Edge distance factor for split rings and dowels | **6.8.5**, Table 96 |
| $K_{S}$ | End distance factor for split rings and dowels | **6.8.5**, Table 93 |
| $K_{def}$ | Deflection factor for duration of load and service conditions for plywood panel products other than plywood solid timber and glulam | **4.6**, Table 38, **5.3**, Table 58, Annex K, Table K.2 |
| $K_{mod}$ | Strength factor for duration of load and service conditions for plywood panel products other than plywood | **4.6**, Table 37, **5.3**, Table 57 |

# Bibliography


**Standards publications**

BS 5268, *Structural use of timber*.

BS 5268-3:1985, *Code of practice for trussed rafter roofs*.

BS 5268-4, *Fire resistance of timber members*.

BS 5268-4.1:1978, *Recommendations for calculating fire resistance of timber structures*.

BS 5268-4.2:1989, *Recommendations for calculating fire resistance of timber stud walls and joisted floor constructions*.

BS 5268-6, *Code of practice for timber frame walls*.

BS 5268-6.1:1996, *Dwellings not exceeding four storeys*.

BS 5268-7, *Recommendations for the calculation basis for span tables*.

BS 6566, *Plywood*.

DD ENV 1099, *Plywood — Biological durability — Guidance for the assessment of plywood in different hazard classes*.

DD ENV 1995-1-1:1994, *Eurocode 5: Design of timber structures — Part 1.1: General rules and rules for buildings (together with United Kingdom National Application Document)*.

BS EN 1912, *Structural timber — Strength classes — Assignment of visual grades and species*.

ISO 3898:1987, *Bases for design of structures — Notations — General symbols*.

**Other references**

[1] TIMBER TRADE FEDERATION (TTF). *Approved certification bodies for the supply of strength graded timber*. London: TTF, 1980.

[2] GREAT BRITAIN. Construction (Design and Management) Regulations 1994. London: The Stationery Office.

[3] INTERNATIONAL COUNCIL FOR BUILDING RESEARCH STUDIES AND DOCUMENTATION. *Symbols for use in structural timber design.* CIB-W18-1. Rotterdam: CIB.

[23] TRADA TECHNOLOGY. *Timber engineering guidance document 6 (GD6). Vibration in timber floors.* High Wycombe: Trada Technology, 1994.[15)]


[15)]Available from TRADA Technology Ltd., Stocking Lane, Highenden Valley, High Wycombe, Bucks HP14 4ND. www.trada.co.uk.

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