

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

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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 BS 5268-2:2002 supersedes BS 5268-2:1996 which is withdrawn.

The start and finish of text introduced or altered by Amendment No. 1 is indicated in the text by tags **[A1]** **<A1]**.

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to x, pages 1 to 170, an inside back cover and a back cover.

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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, connected 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

A1 The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. **A1**

Standards publications

A1 BS 449-2 **A1**, *Specification for the use of structural steel in building — Part 2: Metric units.*

A1 BS 1202-1 **A1**, *Specification for nails — Part 1: Steel nails.*

A1 *Text deleted* **A1**

A1 BS 1210 **A1**, *Specification for wood screws.*

A1 *Text deleted* **A1**

A1 BS 4320 **A1**, *Specification for metal washers for general engineering purposes — Metric series.*

A1 BS 4978, *Visual strength grading of softwood — Specification.* **A1**

A1 *Text deleted* **A1**

A1 BS 5756:2007 **A1**, *Specification for tropical hardwoods graded for structural use.*

A1 *Text deleted* **A1**

A1 BS 6100-8, *Building and civil engineering — Vocabulary — Part 8: Work with timber and wood-based panels.* **A1**

A1 BS 6150, *Painting of buildings — Code of practice.* **A1**

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.*

A1 BS 6399-3 **A1**, *Loading for buildings — Part 3: Code of practice for imposed roof loads.*

A1 BS 6446 **A1**, *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.*

A1 BS 8417, *Preservation of timber — Recommendations.* **A1**

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

A1 BS EN 301 **A1**, *Adhesives, phenolic and aminoplastic, for load-bearing timber structures: classification and performance requirements.*

A1 BS EN 310 **A1**, *Wood-based products — Determination of modulus of elasticity in bending and of bending strength.*

A1 BS EN 312, *Particleboards — Specifications.* **A1**

A1 *Text deleted* **A1**

- BS EN 314-1, *Plywood — Bonding quality — Part 1: Test methods.*
- BS EN 314-2, *Plywood — Bonding quality — Part 2: Requirements.*
- BS EN 315, *Plywood — Tolerances for dimensions.*
- BS EN 322, *Wood-based panels — Determination of moisture content.*
- BS EN 323, *Wood-based panels — Determination of density.*
- BS EN 324-1, *Wood-based panels — Determination of dimensions of boards — Part 1: Determination of thickness, width and length.*
- BS EN 324-2, *Wood-based panels — Determination of dimensions of boards — Part 2: Determination of squareness and edge straightness.*
- BS EN 336, *Structural timber — Sizes, Permissible deviations.*
- BS EN 338, *Structural timber — Strength classes.*
- Text deleted
- BS EN 385, *Finger jointed structural timber — Performance requirements and minimum production requirements.*
- Text deleted
- 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, *Plywood — Specifications.*
- Text deleted
- BS EN 789, *Timber structures — Test methods — Determination of mechanical properties of wood-based panels.*
- BS EN 912, *Timber fasteners — Specifications for connections for timber.*
- 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 12369-2, *Wood-based panels — Characteristic values for structural design — Part 2: Plywood.*
- BS EN 12871, *Wood-based panels — Performance specifications and requirements for load bearing boards for use in floors, walls and roofs.*
- BS EN 14080, *Timber structures — Glue laminated timber — Requirements.*
- BS EN 14081 (all parts), *Timber structures — Strength graded structural timber with rectangular cross section.*
- DD ENV 12872, *Wood-based panels — Guidance for structural panel installation.*
- BS EN ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs.*

Other references

- [4] CANADIAN STANDARDS ASSOCIATION (CSA). *Canadian softwood lumber*. CSA 0141-1994. Rexdale, Ontario: CSA, 1974¹⁾.
- [5] NATIONAL LUMBER GRADES AUTHORITY (NLGA). *National Grading Rules for Dimension Lumber*. Burnaby, BC: NLGA, 1994¹⁾.
- [6] NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY (NIST). *American softwood lumber*. NBS PS 20-70. Washington: NBS, 1986²⁾.
- [7] NATIONAL GRADING RULES FOR DIMENSION LUMBER (NGRDL). *National Grading Rules for Softwood Dimension Lumber*. Portland, OR: West Coast Lumber Inspection Bureau (WCLIB), 1975³⁾.
- [8] CANADIAN STANDARDS ASSOCIATION (CSA). *Canadian Douglas fir plywood*. CSA 0121-M1978. Rexdale, Ontario: CSA¹⁾.
- [9] CANADIAN STANDARDS ASSOCIATION. *Canadian softwood plywood*. CSA 0151-M1978. Rexdale, Ontario: CSA¹⁾.
- [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, 1977⁴⁾.
- [12] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *General rules for the classification of plywood with outer plies of birch*. SFS 2412. Helsinki: SFS, 1971⁵⁾.
- [13] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Quality requirements for appearance of plywood with outer plies of birch*. SFS 2413. Helsinki: SFS, 1971⁵⁾.
- [14] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Finnish combi plywood*. SFS 4091. Helsinki: SFS, 1988⁶⁾.
- [15] SUOMEN STANDARDISOIMISLIITO (SFS), r.y. *Finnish conifer plywood*. SFS 4092. Helsinki: SFS, 1988⁵⁾.
- [16] STANDARDISERINGSKOMMISSIONEN I SVERIGE (SIS). *Wood based sheet material — Manufacture and control of constructional boards*. SBN 1975:5⁶⁾.
- [17] ECONOMIC COMMISSION FOR EUROPE (ECE). *Recommended standard for strength grading of coniferous sawn timber*. ECE Sawn timber. Geneva: United Nations (UN), 1982⁷⁾.
- [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 Office⁹⁾.
- [20] GREAT BRITAIN. Building Standards Scotland. Edinburgh: The Stationery Office, 1990¹⁰⁾.

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.

¹⁰⁾ Available from The Stationery Office, 71 Lothian Road, Edinburgh EH3 9AZ.

[21] NORTHERN IRELAND. Building Regulations (Northern Ireland). Belfast: The Stationery Office, 1994¹¹⁾.

[22] INSTITUTION OF STRUCTURAL ENGINEERS (ISE). *Appraisal of existing structures*. London: ISE, 1980¹²⁾.

1.3 Terms and definitions

For the purposes of BS 5268-2 the terms and definitions given in **A1** BS 6100-8 **A1** and the following apply.

1.3.1

A1 Text deleted **A1**

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

A1 NOTE For the purposes of BS 5268-2, grade stresses for structural timber are derived from the characteristic stresses given in BS EN 338. **A1**

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.

¹¹⁾ Available from The Stationery Office, 16 Arthur Street, Belfast BT1 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;
$\boxed{A_1} g$	dead load; $\langle A_1 \rangle$
h	depth of member, greater transverse dimension of a tension or compression member;
i	radius of gyration;
K	modification factor (always with a subscript); 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;
$\boxed{A_1} q$	imposed load; $\langle A_1 \rangle$
r	radius of curvature;
$\boxed{A_1} s$	spacing; $\langle A_1 \rangle$
t	thickness; thickness of laminations;
u	fastener slip;
α	angle between the direction of the load and the direction of the grain;
η	eccentricity factor;
$\boxed{A_1} \zeta$	deflection factor; $\langle A_1 \rangle$
θ	angle between the longitudinal axis of a member and a connector axis;
λ	slenderness ratio;
σ	stress;
τ	shear stress;
ω	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 (to the grain);
⊥	perpendicular (to the grain);
α	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 1210, BS 5756, BS EN 300, BS EN 301, BS EN 312, BS EN 336, BS EN 338, BS EN 912, BS EN 14080, BS EN 14081

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.

Text deleted

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, A_1 plywood and other panel products A_1 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

A_1 For the purpose of design, loading should be in accordance with BS 6399-1, BS 6399-2 and BS 6399-3 or other relevant standards, where applicable.

The effects of exceptional snow drift loads on roofs, as defined in BS 6399-3 should be checked using the permissible member stresses given in **1.6.3.8** and the permissible fastener loads given in **1.6.3.9**. A_1

A_1 **1.6.3 Accidental damage**

1.6.3.1 General

In addition to designing a structure to support loads 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 collapse to an extent that is disproportionate to the original cause.

The general recommendations in **1.6.1.1** apply to all buildings. The measures required for each Class of building as defined in the National Building Regulations or Standards are as follows:

- a) Class 1 buildings: no additional requirements.
- b) Class 2A buildings either:
 - 1) Option 1. Effective anchorage of suspended floors to load-bearing walls in accordance with **1.6.3.2**; or
 - 2) Option 2. The provision of effective horizontal ties in accordance with **1.6.3.3**.
- c) Class 2B buildings either:
 - 1) Option 1. Effective horizontal ties in accordance with **1.6.3.3** and vertical ties in accordance with **1.6.3.4**; or
 - 2) Option 2. Check for the notional removal of load-bearing elements in accordance with **1.6.3.5**.
- d) Class 3 buildings: The designer should carry out a risk assessment as required by the National Building Regulations or Standards. A_1

1.6.3.2 Effective anchorage of suspended floors

A suspended floor can be considered to be effectively anchored if the connection between the floor and load-bearing wall complies with either:

- Figure M.3; or
- BS 5628-1:2005, Annex D for timber floors supported by load-bearing masonry.

1.6.3.3 Effective horizontal ties

All buildings should be effectively tied together at each principal floor level and at roof level.

Horizontal ties should be provided as follows (see also Figure M.1):

- Peripheral ties with a design capacity of $0.5F_t$ should be provided around the whole perimeter of the building. Ties should be anchored at external and re-entrant corners.
- Internal ties should be provided in two directions approximately at right angles. They should be effectively continuous throughout their length and should be anchored at the periphery of the building. They may be distributed evenly throughout the floor or may be concentrated at column positions. Internal ties should be designed for a load of F_t .
- External columns and load-bearing walls should be tied in by a tie perpendicular to the edge of the building. The tie should be designed for the greater of F_t or 1 % of the maximum design vertical dead and imposed load in the column at that level. Corner columns should be tied in two directions approximately at right angles.

The basic tie force F_t should be calculated as follows:

- For distributed ties: $F_t = 0.5(g_k + q_k)L$ kN/m but not less than 3.5 kN/m.
- For concentrated ties: $F_t = 0.5(g_k + q_k)s_tL$ kN but not less than 10 kN.

where

- g_k the full dead load per unit area of the floor or roof (kN/m²).
- q_k is the full imposed floor or roof load per unit area (kN/m²).
- s_t is the mean spacing of ties transverse to the direction of the tie being considered (m).
- L is the span of tie being considered (m).

When assessing the capacity of an element acting as a tie, in accordance with 1.6.3.8 or its connections in accordance with 1.6.3.9, the tie load can be considered as an alternative load case to any other loads acting on that element.

1.6.3.4 Vertical ties

Each column or wall carrying vertical load should be tied continuously from the lowest to the highest level. The tie should be capable of resisting a tensile force equal to the maximum design load received by the column or wall from any one storey. There should be an effective connection between vertical ties and horizontal ties at each level.

When assessing the capacity of an element acting as a vertical tie, in accordance with 1.6.3.8 or its connections in accordance with 1.6.3.9, the tie load can be considered as an alternative load case to any other loads acting on that element.

1.6.3.5 Notional removal of load-bearing element

The structure should be checked for the effect of the removal, within each storey, of each supporting column, or beam supporting column(s) or load-bearing wall(s), or any nominal length of load-bearing wall, one at a time, to ensure that disproportionate collapse does not occur. The portion of the building at risk of collapse should not exceed the lesser of 15 % of the floor area of that storey or 70 m².

If the area at risk exceeds the limits given then the column, beam or load-bearing wall should be designed as a key element in accordance with 1.6.3.6. **[A]**

A1 The nominal length of a load-bearing wall should be taken as:

- In the case of an external wall, the length measured between vertical lateral restraints.
- In the case of an internal wall, the length measured between effective vertical lateral restraints but not exceeding $2.25h$, where h is the height between horizontal restraints as shown in Figure M.2.

When considering the residual structure the loading should be as defined in **1.6.3.7**. The capacity of any relevant elements should be calculated in accordance with **1.6.3.8** and their connections should be calculated in accordance with **1.6.3.9**.

1.6.3.6 Key element

A key element should be designed for the accidental loading specified in BS 6399-1. Structural elements that provide lateral restraint vital to the stability of a key element should also be designed as a key element. The accidental loading should be applied to the member from all horizontal and vertical directions, in one direction at a time, together with the reactions from other building components attached to the member that are subject to the same accidental loading but limited to the maximum reactions that could reasonably be transmitted, considering the capacity of such members and their connections. The accidental loads should be considered as acting with the loads given in **1.6.3.7**. The capacity of the element should be calculated in accordance with **1.6.3.8** and its connections should be calculated in accordance with **1.6.3.9**.

1.6.3.7 Design loads for the residual structure

When considering design of the residual structure the following loads should be considered, where appropriate:

- the dead load;
- a third of the imposed load, except that in the case of buildings used predominantly for storage, or where the imposed load is of a permanent nature, the full imposed load should be used;
- A third of the imposed roof or snow load;
- 100 % of any ceiling storage loads;
- a third of the wind load.

1.6.3.8 Permissible stresses for accidental load cases

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 by a factor of 2.25.

1.6.3.9 Permissible fastener load for accidental load cases

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 loads on fasteners by a factor of 3.0. In the case of fastenings through particleboard the values recommended for long-term permissible loads should be increased by a factor of 4.0. **A1**

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). ^[A1] Where visual or machine strength graded timber is to be used in service classes 1 or 2, in the assessment by the grading company of fissures and distortions, the mean moisture content of the timber should be 20 % or lower with no moisture content reading to exceed 24 %. ^[A1]

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 ^[A1] BS EN 14080. ^[A1]

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:

- 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;
- 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 $\boxed{A_1}$ BS EN 14081-4 $\boxed{A_1}$ 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.

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 [A1] BS EN 1912. [A1] 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 [A1] BS 8417 [A1]).
- 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 [A1] Table 5, Table 7 and BS EN 1912. [A1] 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 [A1] BS 8417 [A1]), 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 [A1] Table 10, Table 11, Table 12, Table 14 and Table 15. [A1]

[A1] Species that may be machine graded are listed in BS EN 14081-4. [A1]

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 [A1] commonly available target [A1] sizes. For the NLGA and NGRDL structural light framing (SLF), light framing (LF) and stud grades the [A1] commonly available target [A1] 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 [A1] commonly available target [A1] 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. $35(T2) \times 97(T2)$].

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. $47(T1) \times 195(T2)$]. **A1** Timber processed in this way, previously known as “regularized”, is now referred to as “P2E” (i.e. processed on two edges). **A1**

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

A1 All timber used for structural work should be strength graded in accordance with BS EN 14081 by either a grading machine using settings given in BS EN 14081-4, or by visual inspection to a species/grade combination assigned in BS EN 1912 to a strength class. Other visual grades/species are acceptable provided grade strengths and stiffnesses are given in BS 5268-2. **A1**

2.6 Grade stresses for strength classes and individual species

2.6.1 General

A1 Grade stresses for service classes 1 and 2 are given in Table 8 for 15 strength classes, in Table 9 for one special softwood strength class and in Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 for individual softwood and hardwood species.

NOTE Whilst BS 5268-2 refers to the European standard on strength classes, BS EN 338, the strengths and stiffnesses to be used in designs to BS 5268-2 shall be those given in the tables listed above, and not those given in BS EN 338. **A1**

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. **A1** The species and visual grades which meet the requirements of the strength classes are given in Table 5, Table 7 and BS EN 1912. Machine graded timber, meeting the requirements of BS EN 14081, may be graded directly to the strength class boundaries and marked accordingly. **A1**

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.

A1 Table 2 — Text deleted

Table 3 — Text deleted

Table 4 — Text deleted **A1**

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		[A1] <i>Text deleted</i> [A1]	[A1] 1650f-1.5E [A1]	[A1] 1800f-1.6E [A1]	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).						

****[A1]** Table 6 — *Text deleted* **[A1]****

Table 7 — Temperate hardwoods which satisfy the requirements for strength classes graded to **[A1] BS 5756 **[A1]****

Standard name	Grade	Strength class	Joints ^a
Oak	TH1	D30	D30
	TH2	see Table 15	[A1] D30 [A1]
	THA ^b	D40	[A1] D30 [A1]
	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 [A1] Table 15). [A1] ^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 N/mm ²	Tension parallel to grain N/mm ²	Compression parallel to grain N/mm ²	Compression perpendicular to grain ^a N/mm ²		Shear parallel to grain N/mm ²	Modulus of elasticity		Characteristic density, ρ_k ^b kg/m ³	Average density, ρ_{mean} ^b kg/m ³
							Mean N/mm ²	Minimum N/mm ²		
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	$\overline{A_1}$ 9.5 $\overline{A_1}$	6.0	8.2	2.5	2.0	1.10	$\overline{A_1}$ 11 500 $\overline{A_1}$	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 stresses and moduli of elasticity for special softwood 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 ^b , ρ_k	Mean density, ρ_{mean}
	N/mm ²	N/mm ²	N/mm ²	N/mm ²		N/mm ²	N/mm ²		kg/m ³	kg/m ³
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 class TR26 is 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 class C27 should be used for TR26.

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 N/mm ²	Tension parallel to grain ^a N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^b N/mm ²		Mean N/mm ²	Minimum N/mm ²
redwood/whitewood (imported)	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 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 (British grown)	SS	6.2	3.7	6.6	2.4	0.88	11 000	7 000
	GS	4.4	2.6	5.2	2.1	0.88	9 500	6 000
Parana pine (imported)	SS	9.0	5.4	9.5	2.4	1.03	11 000	7 500
	GS	6.4	3.8	8.1	2.2	1.03	9 500	6 000
pitch pine (Caribbean)	SS	10.5	6.3	11.0	3.2	1.16	13 500	9 000
	GS	7.4	4.4	9.4	2.8	1.16	11 000	7 500
western red cedar (imported)	SS	5.7	3.4	6.1	1.7	0.63	8 500	5 500
	GS	4.1	2.5	5.2	1.6	0.63	7 000	4 500
Douglas fir-larch (Canada and USA)	SS	7.5	4.5	7.9	2.4	0.85	11 000	7 500
	GS	5.3	3.2	6.8	2.2	0.85	10 000	6 500
hem-fir (Canada and USA)	SS	7.5	4.5	7.9	1.9	0.68	11 000	7 500
	GS	5.3	3.2	6.8	1.7	0.68	9 000	6 000
Stresses applicable to timber 300 mm deep (or wide); for other section sizes see 2.10.6 and 2.12.2 . 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 N/mm ²	Tension parallel to grain ^a N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^b N/mm ²		Mean N/mm ²	Minimum N/mm ²
spruce-pine-fir (Canada and USA)	SS	7.5	4.5	7.9	1.8	0.68	10 000	6 500
	GS	5.3	3.2	6.8	1.6	0.68	8 500	5 500
Sitka spruce (Canada)	SS	6.6	4.0	7.0	1.7	0.66	10 000	6 500
	GS	4.7	2.8	6.0	1.5	0.66	8 000	5 500
western white woods (USA)	SS	6.6	4.0	7.0	1.7	0.66	9 000	6 000
	GS	4.7	2.8	6.0	1.5	0.66	7 500	5 000
southern pine (USA)	SS	9.6	5.8	10.2	2.5	0.98	12 500	8 500
	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 N/mm ²	Tension parallel to grain N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^a N/mm ²		Mean N/mm ²	Minimum 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 N/mm ²	Tension parallel to grain N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^a N/mm ²		Mean N/mm ²	Minimum 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 N/mm ²	Tension parallel to grain N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^a N/mm ²		Mean N/mm ²	Minimum N/mm ²
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
hem-fir	Stud	4.1	2.5	5.3	1.6	0.56	9 500	6 500
	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 N/mm ²	Tension parallel to grain N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^a N/mm ²		Mean N/mm ²	Minimum 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

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. 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	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
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 (USA and Canada)	900f-1.0E	5.9	3.5	6.8	2.1	0.98	6 500	5 000
	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 (Canada)	900f-1.0E	5.9	3.5	6.8	1.8	0.95	6 500	5 000
	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.
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 N/mm ²	Tension parallel to grain N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^b N/mm ²		Mean N/mm ²	Minimum 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 N/mm ²	Tension parallel to grain ^a N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity	
				Parallel to grain N/mm ²	Perpendicular to grain ^b N/mm ²		Mean N/mm ²	Minimum N/mm ²
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 N/mm ²	Tension parallel to grain ^a N/mm ²	Compression		Shear parallel to grain N/mm ²	Modulus of elasticity		Density	
				Parallel to grain N/mm ²	Perpendicular to grain ^b N/mm ²		Mean N/mm ²	Minimum N/mm ²	Characteristic, ρ_k kg/m ³	Mean, ρ_{mean} kg/m ³
oak	TH1	9.6	5.8	9.3	3.0	2.0	12 500	8 500	$\overline{A_1}$ 580	690 $\overline{A_1}$
	TH2	7.8	4.7	8.4	3.0	2.0	10 500	7 000	$\overline{A_1}$ 580	690 $\overline{A_1}$
	THA	12.6	7.6	10.5	3.0	2.0	13 500	10 500	$\overline{A_1}$ 580	690 $\overline{A_1}$
	THB	9.1	5.5	9.0	3.0	2.0	12 000	7 500	$\overline{A_1}$ 580	690 $\overline{A_1}$
sweet chestnut	TH1	7.6	4.5	8.3	2.3	2.0	11 300	6 300	$\overline{A_1}$ 510	560 $\overline{A_1}$
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 α , 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 A_1 For wind where the largest diagonal dimension of the loaded area a , as defined in BS 6399-2, exceeds 50 m.

^c For wind where the largest diagonal dimension of the loaded area a , as defined in BS 6399-2, does not exceed 50 m. A_1

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. gymnasias 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.

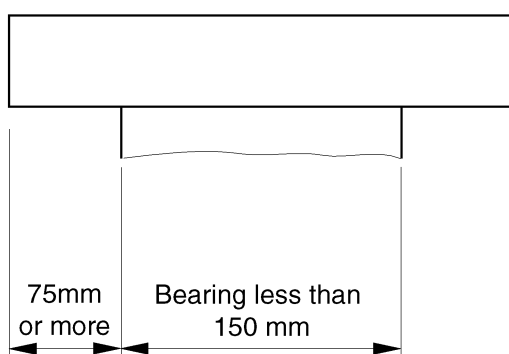


Figure 1 — Position of end bearing

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)]

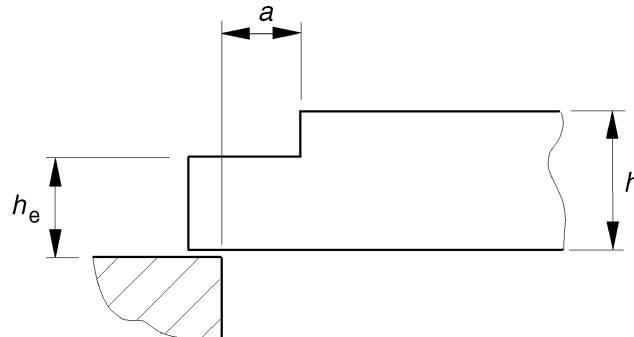
$$K_5 = \frac{h_e}{h};$$

where

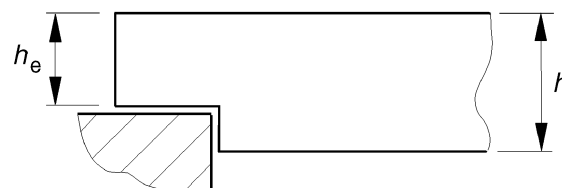
h is the total depth of the beam in millimetres (mm);

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

[A1] The grade bending stresses given in Table 13 apply to solid timber graded in accordance with the North American MSR rules having the particular depth quoted.

The grade bending stresses given in Table 8, Table 9, Table 10, Table 11, Table 12, Table 14 and Table 15 apply to solid timber having a depth, h , of 300 mm. For other depths of beams, the grade bending stresses should be multiplied by the depth modification factor, K_7 , where: **[A1]**

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

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

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

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.

A1 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 the lesser of 0.003 times the span or 14ζ mm, where:

- ζ = 0.86 for floors whose transverse stiffness is provided by the decking/ceiling.
- ζ = 1.00 for floors where there is additional transverse stiffness to that from the decking/ceiling. This additional transverse stiffness may be provided by herringbone strutting or by blocking of depth at least 75 % of the depth of the joists or, in the case of transverse members which are continuous across the joists (i.e. joists with an open-webbed structure), by timbers of depth at least 30 % of the depth of the joists.

NOTE The 14ζ mm deflection is to avoid undue vibration under moving or impact loading. **A1**

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

A1 The grade compression stresses given in Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14 and Table 15 apply to all solid timber members and laminations graded in accordance with BS EN 14081. **A1**

2.11.3 Effective length

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

- Table 21 for the particular end conditions; or
- 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:

- any compression member carrying dead and imposed loads other than loads resulting from wind;
- 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, σ_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:

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

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});
- σ_e is the Euler critical stress $\frac{\pi^2 E}{(L_e/i)^2}$, 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 2.11.3b).

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 connected 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

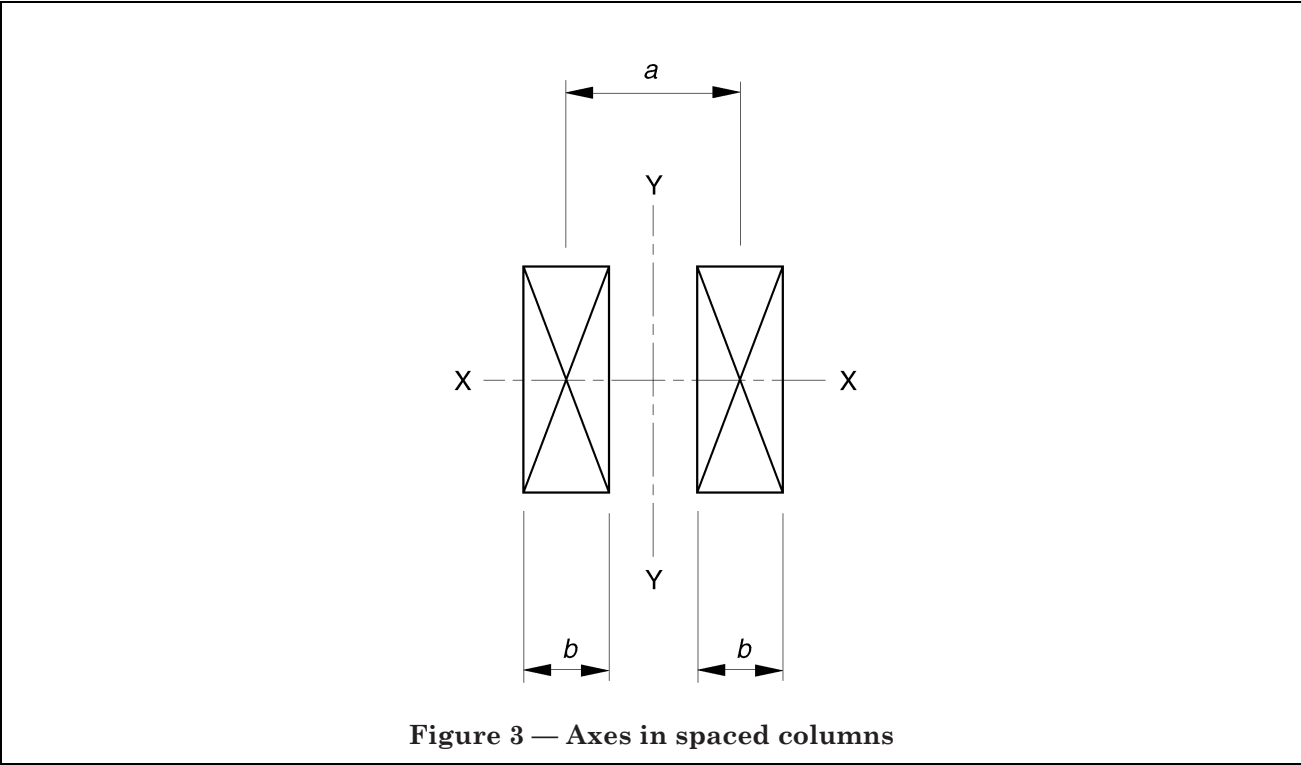
Intermediate packings should be not less than 230 mm long, measured along the axis of the column, and should be designed to transmit, between the abutting face of the packing and one adjacent shaft, a shear force of not less than one half of the corresponding shear force for the end packing (see 2.11.9.1.1).

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.



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
Connected	1.4	1.8	2.2	2.4
Glued	1.1	1.1	1.3	1.4