



BS 5268 : Part 2 : 1988

UDC [624.011.1+674.038.5+691.11] :624.042

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British Standard

Structural use of timber

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

Utilisation du bois en construction

Partie 2. Calcul des charges permmissibles, matériaux et façonnage — Code de bonne pratique

Verwendung von Holz im Bauwesen

Teil 2. Leitfaden über zulässige Beanspruchbarkeit, Werkstoffe und Verarbeitung

British Standards Institution

Foreword

This revision of this Part of BS 5268 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee. It supersedes BS 5268 : Part 2 : 1984 which is withdrawn.

Other Parts of BS 5268 are as follows.

- Part 1 Limit state design, materials and workmanship (for later publication)
- 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 Preservative treatments for constructional timber†
- Part 6 Code of practice for timber frame walls
 - Section 6.1 Dwellings not exceeding three storeys
- Part 7 Recommendations for the calculation basis for span tables*

This standard was originally published as CP 112 in 1952 and revised in 1967. Later during the metrication of the construction industry, a new Part of the code (CP 112 : Part 2 'Metric units') was prepared and published in 1971. That Part however did not involve any change in technical content of Part 1 of the code (except as covered in amendments), having been produced simply by converting the units to the SI system. Both Parts of CP 112 have subsequently been withdrawn.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 has shown the need for a review of the modification factors and stress values in the code. Accordingly, these have been revised to take account of the results of this research and to reflect the properties of construction materials now available in the UK.

Extensive amendment of CP 112 : Part 2 : 1971 had already dealt with some of these changes, but Technical Committee CSB/32, which is responsible for BS 5268, decided that the time had come for a thorough revision of the whole series. This revision of this Part of BS 5268 is part of that process.

In this Part of BS 5268, the recommendations are 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 has superseded the old system which used the numbered visual grades 75, 65, 50 and 40 and no reference to these grades remains in the standard.

In consequence, appendix A of CP 112 : Part 2 : 1971, dealing with sizes and grading of hardwoods and softwoods, has been omitted from this revision.

The scope of the work has been extended to include information concerning additional species of tropical hardwood and grades of plywood and a particular grade of tempered hardboard which has been shown to be suitable for structural use.

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

The introduction of strength classes inevitably entails penalties on particular strength properties for some species when designs are based on a strength class approach. With this approach, however, the supplier has a greater flexibility in the choice of species and grades which he can offer.

When considering the revision of this Part of the standard, the Technical Committee was fully aware that codes of practice for concrete, steel and masonry had been, or were being, produced in a limit state format using partial safety factors. The committee recognizes that eventually it will be necessary to produce a similar type of standard for timber.

However, not only is this revision needed for the reasons given above, it is also essential that an up-dated deterministic code be available to avoid some of the anomalies which would otherwise arise when a limit state standard is introduced. Thus in deriving the recommended stresses for timber, estimates of 5 % lower exclusion values of strength and stiffness and not the 1 % values as in previous codes, are used. Furthermore, the modulus of elasticity values no longer include an element due to shear (i.e. 'true' modulus of elasticity is now tabulated, replacing the 'apparent' modulus of elasticity used in CP 112). These changes are in accordance with the accepted definitions of characteristic values adopted for other materials.

This edition of BS 5268 : Part 2 amends the 1984 edition (now withdrawn) to extend the range of timbers covered and includes the related stresses. New appendices on grade marks for plywood and factors for determining clear wood stresses have also been added. For convenience it was decided not to issue an amendment to cover these changes and to incorporate them in a new edition of this standard. As BS 4978 'Softwood grades for structural use' calls for independent quality assurance, it has been necessary to include appendix P which lists acceptable agencies for grading in accordance with BS 4978. The list was prepared to include those agencies known to have been responsible for grading timber in accordance with BS 4978 prior to 1988. A new independent authority will be set up to consider new applicants and to confirm existing ones.

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 work is done under qualified supervision.

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

* In preparation.

† Revision in preparation.

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Section one. General

1 Scope

This Part of BS 5268 provides guidance on the structural use of timber, plywood, glued laminated timber and tempered hardboard 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 structures incorporating other materials. It also gives recommendations for the design of nailed, screwed, bolted, 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.

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

2 Definitions

For the purposes of this Part of BS 5268 the definitions given in BS 6100 apply together with the following.

2.1 British grown timber. Timber grown within the United Kingdom.

NOTE. For the purpose of this British Standard, species grown in the Irish Republic are given the same rating as British grown timbers.

2.2 clear wood stress. Stress that can safely be permanently sustained by timber containing no visible strength reducing characteristics.

2.3 connector. Device generally consisting of a plate, disc or ring which, when partly 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.

2.4 connector axis. Line joining the centres of a pair of adjacent connectors located on the same surface.

2.5 dry stress*. Stress applicable to material exposed in conditions which would result in solid timber having a specified maximum moisture content.

NOTE. For the purpose of this Part of BS 5268, the moisture content for dry stress should not exceed 18 % in service.

2.6 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.

2.7 glued laminated member. Timber structural member obtained by gluing together a number of laminations having their grain essentially parallel.

2.8 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.

2.9 green timber. Timber, freshly felled, or still containing original free moisture in its cell cavities.

NOTE. For the purposes of this Part of BS 5268, green timber has a moisture content greater than that produced by environmental conditions, which would result in solid timber having a moisture content greater than 18 %.

2.10 horizontally glued laminated member. Glued laminated member whose laminations are parallel to the neutral plane.

2.11 load-sharing system. Assembly of pieces or members which are constrained to act together to support a common load.

2.12 member. Structural component which may be either a piece of solid timber or built up from pieces of timber, plywood, etc. (e.g. floor joist, box beam, member in a truss, etc.).

2.13 permissible stress. Stress that can safely be sustained by a structural material under a particular condition.

NOTE. For the purposes of this Part of BS 5268, it is the product of the grade stress and the appropriate modification factors for section size, service and loading.

2.14 principal member. Individual member on which the integrity of the structure depends (e.g. a trimmer beam).

2.15 strength class. Classification of timber based on particular values of grade stress.

2.16 structural unit. Assembly of members forming the whole or part of a framework (e.g. truss, prefabricated floor and wall, skeleton of a building or a complete structure).

2.17 vertically glued laminated member. Glued laminated member whose laminations are at right-angles to the neutral plane.

2.18 wet stress*. Stress applicable to material exposed in conditions which would result in softwood having a specified minimum moisture content.

NOTE. For the purposes of this Part of BS 5268 the moisture content for wet stress will exceed 18 % in service.

3 Symbols

The symbols used in this Part of BS 5268 are generally in accordance with ISO 3898 published by the International Organization for Standardization, supplemented by the recommendations of CIB-W18-1 'Symbols for use in structural timber design', published by the International Council for Building Research Studies and Documentation, which takes particular account of timber properties.

The symbols used are:

- a* Distance
- A* Area

*A more precise demarcation of wet and dry service conditions has been deliberately avoided. For the purposes of this Part of BS 5268, the dry condition approximates to a moisture content of 18 % or less in softwoods.

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Section one

- b* Breadth of beam, thickness of web, or lesser transverse dimension of a tension or compression member
d Diameter
E Modulus of elasticity
F Force or load
h Depth of beam, greater transverse dimension of a tension or compression member
i Radius of gyration
K Modification factor (always with a subscript)
L Length; span
m Mass
M Bending moment
n Number
r Radius of curvature
t Thickness; thickness of laminations
 α Angle between the direction of the load and the direction of the grain
 η Eccentricity factor
 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
 $\parallel$ Parallel (to the grain)
 $\perp$ 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 factors *K*.

4 Materials

The materials used should comply with the following British Standards:

BS 449, BS 1142, BS 1202, BS 1203, BS 1204, BS 1210, BS 1579, BS 4978, BS 5756

or with accepted standards from other countries, where the following rules in (a) to (h) apply to timber and plywood

graded outside the UK to other than UK rules. Timber stress graded to BS 4978 should be graded under the supervision and bear the mark of a grading agency listed in appendix P.

(a) The grading rules promulgated in accordance with (Canadian Standards Association) CSA 0141 — 1970, 'Canadian softwood lumber' and approved by the Canadian Lumber Standards Accreditation Board (CLSAB) are 'The National Grading Rules for Dimension Lumber' National Lumber Grading Association (NLGA) 1979. The grading agencies approved by the Board are listed in appendix J and it is the products covered by, and bearing the marks of these agencies, to which this Part of BS 5268 refers.

(b) The grading rules promulgated in accordance with National Bureau of Standards NBS PS 20 — 70, 'American softwood lumber' 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. The grading agencies approved by the Board are listed in appendix K, and it is the products covered by and bearing the marks of these agencies to which this standard refers.

(c) (Canadian Standards Association) CSA 0121 — M 1978, 'Canadian Douglas fir plywood', and CSA 0151 — M 1978, 'Canadian softwood plywood' refer to those products covered by, and bearing the mark of, the Council of Forest Industries of British Columbia COFI Plywood Manufacturing Standards.

(d) (National Bureau of Standards) NBS PS 1—74, 'American construction and industrial plywood' refers to those products covered by, and bearing the mark of, the American Plywood Association (APA) or Timberco Inc. (TECO).

(e) Finnish Standard SFS 2412 to 2416 and 4091 to 4093, 'Finnish birch plywood and its structural applications', 'Finnish birch-faced plywood and Finnish conifer plywood' refer to those products covered by, and bearing the mark of, the VTT. Quality Control Contract (1977).

(f) Swedish Standard SBN 1975.5, 'Wood based sheet material — manufacture and control of constructional boards', refers to those products covered by, and bearing the mark of, Statens Planverk.

(g) ECE (Economic Commission for Europe) Sawm timber (1982) 'Recommended standard for stress grading of coniferous sawn timber'.

(h) The 'North American Export Standard for Machine Stress-Rated Lumber', produced by the National Lumber Grades Authority (NLGA), Southern Pine Inspection Bureau (SPIB), West Coast Lumber Inspection Bureau (WCLIB), Western Woods Products Association (WWPA), 1 August 1986, is approved by the Canadian Lumber Standards Accreditation Board (CLSAB) and the American Lumber Standards Board of Review. It is applicable to machine stress-rated timber bearing the mark of an approved agency as listed in appendix L.

5 Design considerations

5.1 General

5.1.1 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 this Part of BS 5268, the whole dead, imposed and wind loading and all other types of loading referred to in BS 5268.

The design requirements of this Part of BS 5268 may be satisfied either by calculation, using the laws of structural mechanics, or by load testing in accordance with section eight.

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 made by another designer.

To ensure a robust and stable design it is necessary to:

- (a) consider the geometry of the structure;
- (b) ensure any required interaction and connections between timber load-bearing elements and between such elements and other parts of the structure;
- (c) provide suitable bracing or diaphragm effect in planes parallel to the direction of the lateral forces acting on the whole structure.

In addition, the designer should state whether special precautions or temporary propping are necessary to ensure overall stability of the structure or its components during construction.

The strength properties of timber, plywood, hardboard and joints are influenced by service and loading conditions. The grade stresses for materials and basic loads for fasteners given in this Part of BS 5268 apply to specific conditions and should be multiplied by the appropriate modification factors given in this Part of BS 5268 when the actual service and loading conditions are different.

5.1.2 With regard to the design process, design, including design for construction durability and use in service should be considered as a whole. Unless clearly defined standards for materials, production, workmanship and maintenance are provided and complied with the design intentions may not be realized.

5.1.3 With regard to basic assumptions covering durability, workmanship and materials, it is assumed that the quality of the timber and other materials, and of the workmanship as verified by inspections, is adequate for safety, serviceability and durability.

5.2 Loading

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

5.3 Accidental damage (including exceptional snow drift loads)

In addition to designing a structure to support loads arising from normal use, there should be a reasonable probability that the structure will not collapse catastrophically because of misuse or accident. No structure can be expected to be resistant to the excessive loads or forces that could arise from an extreme cause, but it should not be damaged to an extent which is disproportionate to the original cause. The effects of exceptional loads caused by 'local drifting of snow' on roofs, as defined in BS 6399 : Part 3, should also be checked on this basis.

Whilst, in general, the hazards and safeguards previously described should always be considered by the designer, no specific design requirements are normally necessary for buildings up to four storeys.

However, for buildings exceeding four storeys, where timber is often used in conjunction with other structural materials which normally perform the main load-bearing function, the effect on the structure of accidental loading should be considered as required by the relevant standards for such materials.

Because of the particular occupancy of a structure (e.g. flour mill, chemical plant, etc.), it may be necessary to consider the effect of particular hazards and to ensure that, in the event of an accident, there is an acceptable probability of the structure continuing to perform its main function after the event, even if in a damaged condition. Also, where there is a possibility of vehicles running into and damaging vital load-bearing members of the structure in the ground floor, the provision of bollards, walls, retaining earth banks, etc., should be considered.

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

5.4 Moisture content

Softwood imported from Europe normally is dried to a moisture content below 23 % before shipment to the UK. Softwood of North American origin may be imported in either a green or dry condition. In regard to the green condition it will be usual for the timber to be dipped in a fungal inhibitor prior to shipment. Imports of dry timber from North America are generally of those structural sizes which are surfaced on four sides and are commonly known as CLS or ALS (Canadian Lumber Standards or American Lumber Standards): see appendix A of BS 4471 : Part 1 : 1978. Imported hardwoods from most sources are normally dried before shipment only to such an extent as will avoid deterioration during passage to the UK, but it is now sometimes possible to have kiln drying done in the country of origin. Supplies of hardwood dry enough for immediate use generally are available.

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Section one

The following relevant facts about the response of timber and wood based panel products to changes in moisture content should be borne in mind by those specifying, supplying and designing in timber.

- (a) At a moisture content below about 30 % timber shrinks or swells, and its strength properties increase or decrease, as its moisture content is reduced or increased.
- (b) Wood is less prone to decay if its moisture content is below 25 %, and may be considered immune below 20 %.
- (c) All timber, whether imported or British grown, which is thoroughly air-dried in this country normally attains a moisture content between 17 % and 23 %, depending upon weather conditions at the end of the drying period.
- (d) Plywood is produced in the dry condition with a moisture content of approximately 7 %. Changes in strength and dimensions will occur with changes in exposure condition. The hygroscopic properties differ from those for solid timber, and under the same exposure conditions its equilibrium moisture content can be as much as 3 % less than the value for solid timber.
- (e) Hardboard is produced in the dry condition with a moisture content of approximately 9 %. In conditions of exposure which would result in solid timber attaining a moisture content of 18 %, tempered hardboard would attain a moisture content not exceeding 10 %. However, attention is drawn to the need to condition boards before fixing (see clause 31).

Ideally, timber and wood based panel products should have a moisture content, when installed, close to the moisture contents they will attain in service. Table 1 gives average moisture contents in use for softwoods and hardwoods for selected categories of end use.

During erection of a structure higher moisture contents may be accepted provided it is known that the timber will dry to the desired moisture content before it is required to support the design load. Recommended upper levels of moisture content are also given in table 1. Higher than normal moisture contents may also be acceptable where the appearance effects of any shrinkage are not considered to be important.

It is essential that designers and specifiers assess the moisture contents which will be acceptable in any particular case, and table 1 can give only general guidance in this respect. However, for softwoods specified to be at an average moisture content of less than 18 % at time of erection, extra drying costs should be anticipated. Suppliers should be consulted in the case of hardwoods, since moisture content varies with species and size.

Care should be taken on site to ensure that material supplied in a dry condition is adequately protected from the weather (see clause 52).

The moisture content of timber used in the manufacture of glued-laminated members should comply with BS 4169.

The moisture content of timber to be finger jointed should comply with BS 5291.

The moisture content of materials used in components manufactured from separate pieces of timber, plywood or tempered hardboard that are fastened together with glue (e.g. box beams, single web beams, stressed skin panels, glued gussets) should comply with BS 6446.

Timber treated with a water-borne preservative should be dried before being used in a structure whose design has been based on dry stresses.

5.5 Service exposure conditions

Because of the effect of moisture content on strength properties, the permissible stresses used in design should be those corresponding to the moisture content that the particular member will attain in service. It is not possible to cover all service conditions and for the purposes of this Part of BS 5268 the following two exposure conditions only are defined.

(a) *Dry exposure.* All service conditions where the air temperature and humidity would result in solid timber attaining an equilibrium moisture content not exceeding 18 % for any significant period. This exposure includes most covered buildings, and internal uses. Stresses are given in this Part of BS 5268 for the dry exposure condition and are identified as dry stresses.

(b) *Wet exposure.* All service conditions, either in contact with water, or where the air temperature and humidity would result in solid timber attaining an equilibrium

Table 1. Moisture content of timber for categories of end use

Position of timber in building	Average moisture content attained in service conditions	Moisture content which should not be exceeded at time of erection
External uses fully exposed	% 18 or more	% —
Covered and generally unheated	18	24
Covered and generally heated	16	21
Internal in continuously heated building	14	19

moisture content exceeding 18 % for any significant period. Permissible stresses should be obtained for the wet exposure condition by multiplying the dry stresses by appropriate modification factors and such stresses are identified as wet stresses (see 10.2).

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

5.6 Duration of loading

The grade stresses and the joint strengths given in this Part of BS 5268 are applicable to long term loading. Because timber and timber 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 this Part of BS 5268.

5.7 Section size

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

- (a) 300 mm deep (or wide, for tension) if assigned to a strength class or if graded to BS 4978, BS 5756 or NLGA or NGRDL Joist and Plank rules;
- (b) 89 mm deep (or wide, for tension) if graded to NLGA or NGRDL Structural Light Framing, Light Framing or Stud rules;
- (c) of the particular section size quoted if graded to North American 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 (a) and (b) by the modification factors specified in the appropriate sections of this Part of BS 5268.

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

5.8 Load-sharing systems

The grade stresses given in this Part of BS 5268 are applicable to individual pieces of structural timber. Where two or more 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 may be permitted in accordance with the appropriate sections of this Part of BS 5268.

5.9 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 actual cross section appropriate to the exposure condition, less due allowance for the reduction in area caused by sinkings, notches, bolt or screw holes, mortices, etc., either at that section or within such a distance from it as would affect the strength at that section.

5.10 Structural members

Structural members should be so proportioned that the stresses or deformations 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 this Part of BS 5268.

5.11 Structural frameworks

5.11.1 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. The recommendations for trussed rafters appear in BS 5268 : Part 3.

5.11.2 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.

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

5.12 Floor and roof boarding

5.12.1 Lateral distribution of load. Where the boards, other than roof boarding on pitched roofs, are not tongued and grooved, each individual board should be designed to carry the full imposed load given in CP 3 : Chapter V as the minimum load per 300 mm width of boarding.

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

5.12.2 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 two. Timber

6 General

This section gives recommendations for the structural use of the softwood and hardwood species and species combinations listed in appendix A.

This section is applicable to all sizes of timber. Generally however, it will be found uneconomic to specify sizes other than those recommended in BS 4471 for softwoods or BS 5450 for hardwoods.

7 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, this Part of BS 5268 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 tables 3 to 8. For some applications it may be necessary to specify particular species from within a strength class to take account of particular characteristics, e.g. natural durability, amenability to preservatives (see BS 5268 : Part 5), glues and fasteners.

Stress values for individual species and grades are given in tables 10, 11, 12, 13 and 15. Modification factors for section size for North American timbers are given in table 14.

Radiata Pine (New Zealand) is machine stress graded in accordance with BS 4978 to comply directly with the strength requirements for strength classes SC2, SC3, SC4 and SC5 (see item (a) of clause 9 and table 9).

8 Dimensions and geometrical properties

It is essential to include in specifications, designs and drawings the required actual dimensions of members. Guidance on movement due to moisture changes and allowance for resawing and processing may be obtained from BS 4471 and BS 5450.

Where a softwood member is specified and supplied in accordance with the requirements of BS 4471, and a hardwood member is specified and supplied in accordance with the requirements of BS 5450, the geometrical properties given in appendix D for softwoods, and appendix E for hardwoods, should be used in designing for the dry exposure condition.

For members specified and supplied in accordance with BS 4471 or BS 5450, the geometrical properties of sections, for use in designing for the wet exposure condition, should be obtained by multiplying the corresponding values in appendices D and E by the modification factor K_1 given in table 2.

Table 2. Modification factor K_1 by which the geometrical properties of timber for the dry exposure condition should be multiplied to obtain values for the wet exposure condition

Geometrical property	Value of K_1
Thickness, width, radius of gyration	1.02
Cross-sectional area	1.04
First moment of area, section modulus	1.06
Second moment of area	1.08

9 Grades

All timber used for structural work should be stress graded either by visual inspection or by an approved stress grading machine operated in accordance with the requirements of BS 4978. The stresses given in this Part of BS 5268 apply only to timber graded in accordance with the following rules and to the grades indicated.

(a) BS 4978 : 1973 'Timber grades for structural use', for the visual grades designated GS and SS and the machine grades designated MGS, MSS, M50 and M75, and to additional machine grades selected to comply with the strength requirements for the strength classes given in this Part of BS 5268 (see clause 10). The S6, S8, MS6 and MS8 grades of the ECE 'Recommended standard for stress grading of coniferous sawn timber' (1982) may be substituted for GS, SS, MGS and MSS respectively.

(b) 'National grading rules for dimension lumber', Canada, NLGA 1979 and the 'National grading rules for softwood dimension lumber', NGRDL, 1975 for the grades designated:

- (1) Structural Joists and Planks – Select Structural (Sel), No. 1, No. 2 and No. 3.
- (2) Structural Light Framing – Select Structural (Sel), No. 1, No. 2 and No. 3.
- (3) Light Framing – Construction (Const), Standard (Std) and Utility (Util).
- (4) Stud.

(c) BS 5756 : 1980 'Tropical hardwoods graded for structural use', for the visual grade designated HS (which stands for Hardwood Structural).

(d) North American Export Standard for Machine Stress-Rated Lumber, 1 August 1986, for the machine grades designated 900f-1.0E, 1200f-1.2E, 1450f-1.3E, 1650f-1.5E, 1800f-1.6E, 1950f-1.7E, and 2100f-1.8E.

10 Grade stresses for strength classes and individual species

10.1 General

Grade stresses for the dry exposure condition are given in table 9 for nine strength classes, and in tables 10, 11, 12, 13 and 15 for individual softwood and hardwood species and grades. Because it is difficult and expensive to artificially dry timber more than 75 mm thick, unless it is specially dried the wet stresses and moduli should normally be used for solid timber members more than 100 mm thick.

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

For designs based on strength classes, the material specification should indicate the strength class, whether softwood or hardwood, or if the choice of material is limited by factors other than strength, the particular species required. The species and visual grades which meet the requirements of the strength classes are given in tables 3 to 8. The machine grades MGS, MSS, M50 and M75 have been included in table 10 since control information for their selection is widely available. It will be possible however to machine stress grade timber in accordance with BS 4978

Table 3. Softwood species/grade* combinations which satisfy the requirements for strength classes: graded to BS 4978

Standard name	Strength class†				
	SC1	SC2	SC3	SC4	SC5‡
<i>Imported</i>					
Parana pine			GS	SS	
Pitch pine (Caribbean)			GS		SS
Redwood			GS/M50	SS	M75
Whitewood			GS/M50	SS	M75
Western red cedar	GS	SS			
Douglas fir-larch (Canada)			GS	SS	
Douglas fir-larch (USA)			GS	SS	
Hem-fir (Canada)			GS/M50	SS	M75
Hem-fir (USA) §			GS	SS	
Spruce-pine-fir (Canada) §			GS/M50	SS/M75	
Sitka spruce (Canada) ¶		GS	SS		
Western whitewoods (USA) ¶	GS		SS		
Southern pine (USA)			GS	SS	
<i>British grown</i>					
Douglas fir		GS	M50/SS		M75
Larch			GS	SS	
Scots pine			GS/M50	SS	M75
Corsican pine		GS	M50	SS	M75
European spruce ¶	GS	M50/SS	M75		
Sitka spruce ¶	GS	M50/SS	M75		

*Machine grades MGS and MSS are interchangeable with GS and SS grades respectively.

The S6, S8, MS6 and MS8 grades of the ECE 'Recommended standard for stress grading of coniferous sawn timber' (1982) may be substituted for GS, SS, MGS and MSS respectively.

†A species/grade combination from a higher strength class (see table 9) may be used where a lower strength class is specified.

‡All softwoods classified as or machine graded to strength class SC5, except pitch pine and southern pine (USA), should use the fastener loads tabulated for strength classes SC3 and SC4.

§ For grades of hem-fir (USA) and spruce-pine-fir (Canada) classified as or machine graded to strength classes other than SC1 and SC2, the values of lateral load perpendicular to the grain for bolts and timber connectors should be multiplied by the joint/class modification factor K_{42} which has the value 0.9.

¶ All grades of British grown Sitka spruce, Canadian Sitka spruce, British grown European spruce and western whitewoods (USA) should use the fastener loads tabulated for strength classes SC1 and SC2.

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Section two

directly to the stresses required for each of the strength classes.

A species/grade combination has been assigned to a strength class if the bending and tension* stresses for the combination, and appropriate to a depth (or width for tension) of 300 mm, are not less than the class stresses, and if the compression parallel to the grain stress, the shear parallel to the grain stress and the moduli of elasticity are not less than 95 % of the class values. It is recognized therefore that in some instances minor advantage may accrue from the use of strength classes rather than individual species and grade.

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

10.2 Wet exposure stresses

Grade stress values for the wet exposure condition should be obtained by multiplying the dry stresses and moduli given in tables 9, 10, 11, 12, 13 and 15 by the modification factor K_2 from table 16.

Table 4. North American softwood species/grade combinations which satisfy the requirements for strength classes: NLGA and NGRDL Joist and Plank grades*

Standard name and origin	Strength class†				
	SC1	SC2	SC3	SC4	SC5
Douglas fir-larch (Canada)	No. 3		No. 1, No. 2	Sel	
Douglas fir-larch (USA)	No. 3		No. 1, No. 2	Sel	
Hem-fir (Canada)	No. 3		No. 1, No. 2	Sel	
Hem-fir (USA)‡	No. 3		No. 1, No. 2	Sel	
Spruce-pine-fir (Canada)‡	No. 3		No. 1, No. 2	Sel	
Sitka spruce (Canada)§	No. 3	No. 1, No. 2	Sel		
Western whitewoods (USA)§	No. 3	No. 1, No. 2	Sel		
Southern pine (USA)			No. 1, No. 2, No. 3		Sel

*Joist and Plank No. 3 grade should not be used for tension members.

†These classifications apply only to timber of a size not less than 38 mm X 114 mm.

A species/grade combination from a higher strength class (see table 9) may be used where a lower strength class is specified.

‡For grades of hem-fir (USA) and spruce-pine-fir (Canada) classified as or machine graded to strength classes other than SC1 and SC2, the values of lateral load perpendicular to the grain for bolts and timber connectors should be multiplied by the joint/class modification factor K_{42} which has the value 0.9.

§All grades of Sitka spruce (Canada) and western whitewoods (USA) should use the fastener loads tabulated for strength classes SC1 and SC2.

*Note that although the North American Joist and Plank No. 3, Structural Light Framing No. 3, Light Framing and Stud grades have been assigned to strength classes they are considered unsuitable for tension members and no tension stresses have been assigned to these grades.

Table 5. North American softwood species/grade combinations* which satisfy the requirements for strength classes: NLGA and NGRDL Structural Light Framing grades†

Section size (actual)	Standard name and origin	Strength class‡				
		SC1	SC2	SC3	SC4	SC5
mm 38 X 89	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) ¶ Western whitewoods (USA) ¶ Southern pine (USA)	No. 3 No. 3 No. 3 No. 3 No. 3 No. 3 No. 3	 No. 1, No. 2 No. 1, No. 2	No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 Sel Sel No. 1, No. 2, No. 3	Sel Sel Sel Sel Sel	 Sel
38 X 38	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) ¶ Western whitewoods (USA) ¶ Southern pine (USA)	No. 3 No. 3 No. 3 No. 3 No. 3 No. 3 No. 3	 No. 1, No. 2 No. 1, No. 2	No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 Sel Sel No. 3	Sel Sel Sel Sel Sel	 Sel
38 X 63	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) ¶ Western whitewoods (USA) ¶ Southern pine (USA)	No. 3 No. 3 No. 3 No. 3 No. 3 No. 3 No. 3	 No. 1, No. 2 No. 1, No. 2	No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 No. 1, No. 2 Sel Sel No. 3	Sel Sel Sel Sel Sel	 Sel
63 X 63	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) ¶ Western whitewoods (USA) ¶ Southern pine (USA)	No. 3 No. 3 No. 3 No. 3 No. 3 No. 3 No. 3	 	Sel Sel Sel Sel Sel Sel No. 3		 Sel
63 X 89 and 89 X 89	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) ¶ Western whitewoods (USA) ¶ Southern pine (USA)			Sel Sel Sel Sel Sel Sel Sel	Sel	

* The size modification factors from table 14 are included in the stresses used to assign these species/grade combinations to the strength classes.

† Structural Light Framing No. 3 grade should not be used for tension members.

‡ A species/grade combination from a higher strength class (see table 9) may be used where a lower strength class is specified.

§ For grades of hem-fir (USA) and spruce-pine-fir (Canada) classified as or machine graded to strength classes other than SC1 and SC2 the values of lateral load perpendicular to the grain for bolts and timber connectors should be multiplied by the joint/class modification factor K_{42} which has the value 0.9.

¶ All grades of Sitka spruce (Canada) and western whitewoods (USA) should use the fastener loads tabulated for strength classes SC1 and SC2.

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Table 6. North American softwood species/grade combinations* which satisfy the requirements for strength classes: NLGA and NGRDL Light Framing and Stud grades†

Section size (actual)	Standard name and origin	Strength class‡				
		SC1	SC2	SC3	SC4	SC5
mm 38 X 89	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Std, Stud, Util Std, Stud, Util Std, Stud, Util Std, Stud, Util Std, Stud, Util Std, Stud Std, Stud Util	Const Const Const Const Const Const Const Std	Const, Stud		
38 X 38	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Stud Stud Stud Stud Stud Const, Stud Const, Stud Std	Const Const Const Const Const	Const, Stud		
38 X 63	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud	Const, Std	Stud		
63 X 63	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud Const, Std, Stud	Const, Std	Stud		
63 X 89 and 89 X 89	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Std, Util Std, Util Std, Util Std, Util Std Std Util	Const Const Const Const Const Const Std	Const		
38 X 114¶ and 38 X 140¶	Douglas fir-larch (Canada) Douglas fir-larch (USA) Hem-fir (Canada) Hem-fir (USA) § Spruce-pine-fir (Canada) § Sitka spruce (Canada) Western whitewoods (USA) Southern pine (USA)	Stud Stud Stud Stud Stud Stud Stud	Stud			

*The size modification factors from table 14 are included in the stresses used to assign these species/grade combinations to the strength classes.

†Light Framing and Stud grades should not be used for tension members.

‡A species/grade combination from a higher strength class (see table 9) may be used where a lower strength class is specified.

§For grades of hem-fir (USA) and spruce-pine-fir (Canada) classified as or machine graded to strength classes other than SC1 and SC2, the values of lateral load perpendicular to the grain for bolts and timber connectors should be multiplied by the joint/class modification factor K_{42} which has the value 0.9.

¶Available in Stud grade only.

Table 7. North American softwood species/grade combinations* which satisfy the requirements for strength classes: North American Machine Stress-Rated grades

Surfaced size †	Strength class‡				
	SC1	SC2	SC3	SC4	SC5
mm					
38 X 63	900f-1.0E	1200f-1.2E	1450f-1.3E	1650f-1.5E 1800f-1.6E	1950f-1.7E 2100f-1.8E
38 X 89 } 38 X 72 }	900f-1.0E	1200f-1.2E	1450f-1.3E	1650f-1.5E	1800f-1.6E 1950f-1.7E 2100f-1.8E
38 X 114	900f-1.0E	1200f-1.2E	1450f-1.3E	1650f-1.5E	1800f-1.6E 1950f-1.7E 2100f-1.8E
38 X 140	900f-1.0E	1200f-1.2E	1450f-1.3E	1650f-1.5E	1800f-1.6E 1950f-1.7E 2100f-1.8E
38 X 184	900f-1.0E	1200f-1.2E	1450f-1.3E	—	1650f-1.5E 1800f-1.6E 1950f-1.7E 2100f-1.8E
38 X 235	900f-1.0E	1200f-1.2E	1450f-1.3E	—	1650f-1.5E 1800f-1.6E 1950f-1.7E 2100f-1.8E
38 X 285	900f-1.0E	1200f-1.2E	1450f-1.3E	—	1650f-1.5E 1800f-1.6E 1950f-1.7E 2100f-1.8E

* This table is applicable only to the following species combinations:

Douglas fir-larch (Canada)
Douglas fir-larch (USA)
Hem-fir (Canada)
Hem-fir (USA) §
Spruce-pine-fir (Canada) §
Southern pine (USA).

† Surfaced size measured at 19 % moisture content.

‡ A species/grade combination from a high strength class (see table 9) may be used where a lower strength class is specified.

§ For grades of hem-fir (USA) and spruce-pine-fir (Canada) classified as or machine graded to strength classes other than SC1 and SC2, the values of lateral load perpendicular to the grain for bolts and timber connectors should be multiplied by the joint/class modification factor K_{42} which has the value 0.9.

Table 8. Tropical hardwoods which satisfy the requirements for strength classes: graded to the HS grade of BS 5756

Standard name	Strength class
Iroko Jarrah Teak	SC5
Merbau Opepe	SC6
Karri Keruing	SC7
Balau Ekki Kapur Kempas	SC8
Greenheart	SC9

Table 9. Grade stresses and moduli of elasticity for strength classes: for the dry exposure condition

Strength class	Bending parallel to grain	Tension parallel to grain	Compression parallel to grain	Compression perpendicular to grain*		Shear parallel to grain	Modulus of elasticity		Approximate density†
							Mean	Minimum	
SC1	N/mm ² 2.8	N/mm ² 2.2‡	N/mm ² 3.5	N/mm ² 2.1	N/mm ² 1.2	N/mm ² 0.46	N/mm ² 6800	N/mm ² 4500	kg/m ³ 540
SC2	4.1	2.5‡	5.3	2.1	1.6	0.66	8000	5000	540
SC3	5.3	3.2‡	6.8	2.2	1.7	0.67	8800	5800	540
SC4	7.5	4.5‡	7.9	2.4	1.9	0.71	9900	6600	590
SC5	10.0	6.0‡	8.7	2.8	2.4	1.00	10700	7100	590/760
SC6§	12.5	7.5	12.5	3.8	2.8	1.50	14100	11800	840
SC7§	15.0	9.0	14.5	4.4	3.3	1.75	16200	13600	960
SC8§	17.5	10.5	16.5	5.2	3.9	2.00	18700	15600	1080
SC9§	20.5	12.3	19.5	6.1	4.6	2.25	21600	18000	1200

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

†Since many species may contribute to any of the strength classes, the values of density given in this table may be considered only crude approximations. When a more accurate value is required it may be necessary to identify individual species and utilize the values given in appendix A. The higher value for SC5 is more appropriate for hardwoods.

‡Note the Light Framing, Stud, Structural Light Framing No. 3 and Joist and Plank No. 3 grades should not be used in tension.

§Classes SC6, SC7, SC8 and SC9 will usually comprise the denser hardwoods.

Table 10. Grade stresses for softwoods: graded to BS 4978 rules: for the dry exposure condition

Standard name	Grade	Bending parallel to grain*	Tension parallel to grain*	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpen- dicular to grain†		Mean	Minimum
		N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
Redwood/whitewood (imported) and Scots pine, (British grown)	SS/MSS	7.5	4.5	7.9	2.1	0.82	10500	7000
	GS/MGS	5.3	3.2	6.8	1.8	0.82	9000	6000
	M75	10.0	6.0	8.7	2.4	1.32	11000	7000
	M50	6.6	4.0	7.3	2.1	0.82	9000	6000
Corsican pine (British grown)	SS/MSS	7.5	4.5	7.9	2.1	0.82	9500	6500
	GS/MGS	5.3	3.2	6.8	1.8	0.82	8000	5000
	M75	10.0	6.0	8.7	2.4	1.33	10500	7000
	M50	6.6	4.0	7.3	2.0	0.83	9000	5500
Sitka spruce and European spruce (British grown)	SS/MSS	5.7	3.4	6.1	1.6	0.64	8000	5000
	GS/MGS	4.1	2.5	5.2	1.4	0.64	6500	4500
	M75	6.6	4.0	6.4	1.8	1.02	9000	6000
	M50	4.5	2.7	5.5	1.6	0.64	7500	5000
Douglas fir (British grown)	SS/MSS	6.2	3.7	6.6	2.4	0.88	11000	7000
	GS/MGS	4.4	2.6	5.6	2.1	0.88	9500	6000
	M75	10.0	6.0	8.7	2.9	1.41	11000	7500
	M50	6.6	4.0	7.3	2.4	0.88	9500	6000
Larch (British grown)	SS	7.5	4.5	7.9	2.1	0.82	10500	7000
	GS	5.3	3.2	6.8	1.8	0.82	9000	6000
Parana pine (imported)	SS	9.0	5.4	9.5	2.4	1.03	11000	7500
	GS	6.4	3.8	8.1	2.2	1.03	9500	6000
Pitch pine (Caribbean)	SS	10.5	6.3	11.0	3.2	1.16	13500	9000
	GS	7.4	4.4	9.4	2.8	1.16	11000	7500
Western red cedar (imported)	SS	5.7	3.4	6.1	1.7	0.63	8500	5500
	GS	4.1	2.5	5.2	1.6	0.63	7000	4500
Douglas fir-larch (Canada)	SS	7.5	4.5	7.9	2.4	0.85	11000	7500
	GS	5.3	3.2	6.8	2.2	0.85	10000	6500
Douglas fir-larch (USA)	SS	7.5	4.5	7.9	2.4	0.85	11000	7500
	GS	5.3	3.2	6.8	2.2	0.85	9500	6000
Hem-fir (Canada)	SS/MSS	7.5	4.5	7.9	1.9	0.68	11000	7500
	GS/MGS	5.3	3.2	6.8	1.7	0.68	9000	6000
	M75	10.0	6.0	9.3	2.4	1.13	12000	8000
	M50	6.6	4.0	7.7	2.1	0.71	10500	7000
Hem-fir (USA)	SS	7.5	4.5	7.9	1.9	0.68	11000	7500
	GS	5.3	3.2	6.8	1.7	0.68	9000	6000
Spruce-pine-fir (Canada)	SS/MSS	7.5	4.5	7.9	1.8	0.68	10000	6500
	GS/MGS	5.3	3.2	6.8	1.6	0.68	8500	5500
	M75	9.7	5.8	8.5	2.1	1.10	10500	7000
	M50	6.2	3.7	7.1	1.8	0.68	9000	5500
Sitka spruce (Canada)	SS	6.6	4.0	7.0	1.7	0.66	10000	6500
	GS	4.7	2.8	6.0	1.5	0.66	8000	5500
Western whitewoods (USA)	SS	6.6	4.0	7.0	1.7	0.66	9000	6000
	GS	4.7	2.8	6.0	1.5	0.66	7500	5000
Southern pine (USA)	SS	9.6	5.8	10.2	2.5	0.98	12500	8500
	GS	6.8	4.1	8.7	2.2	0.98	10500	7000
Radiata pine (New Zealand)‡	SS	7.5	4.5	7.9	1.9	0.93	9000	6000

*Stresses applicable to timber 300 mm deep (or wide); for other section sizes see 14.6 and 16.2.

†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.

‡The SS grade of this species is not available. These stresses are given only for use in determining stresses for clear wood and glued laminated timber using modification factors K_{74} to K_{77} and K_{15} to K_{29} .

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Table 11. Grade stresses for Canadian softwoods: graded to NLGA rules: for the dry exposure condition

NOTE. Bending and tension stresses for SLF, LF and Stud grades are applicable to depths or widths of 89 mm (see 14.6 and 16.2)

Standard name	Grade	Bending parallel to grain	Tension parallel to grain	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpen- dicular to grain §		Mean	Minimum
Douglas fir-larch	J & P*	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
	Sel	8.0	6.2	8.8	2.7	0.93	12500	8500
	No. 1	5.6	4.3	7.9	2.7	0.93	11000	7500
	No. 2	5.6	4.3	6.9	2.4	0.93	11000	7500
	No. 3	4.1	—	5.3	1.8	0.61	10500	6500
	SLF†							
	Sel	9.8	7.1	8.8	2.7	0.93	12500	8500
	No. 1	6.4	4.9	7.9	2.7	0.93	11000	7500
	No. 2	6.4	4.9	6.9	2.4	0.93	11000	7500
	No. 3	4.7	—	5.3	1.8	0.61	10500	6500
	LF‡							
	Const	5.4	—	6.1	2.7	0.93	11000	7500
	Std	4.0	—	4.6	2.4	0.93	10500	7000
	Util	3.2	—	3.4	1.8	0.61	10500	7000
	Stud‡	4.7	—	5.3	1.8	0.61	10500	7000
Hem-fir	J & P*							
	Sel	8.0	6.2	8.8	2.1	0.71	12000	8500
	No. 1	5.6	4.3	7.9	2.1	0.71	10500	7000
	No. 2	5.6	4.3	6.9	1.8	0.71	10500	7000
	No. 3	4.1	—	5.3	1.4	0.47	10500	6500
	SLF†							
	Sel	9.1	7.1	8.8	2.1	0.71	12000	8500
	No. 1	6.4	4.9	7.9	2.1	0.71	10500	7000
	No. 2	6.4	4.9	6.9	1.8	0.71	10500	7000
	No. 3	4.7	—	5.3	1.4	0.47	10500	6500
	LF‡							
	Const	5.4	—	6.1	2.1	0.71	10500	7000
	Std	4.0	—	4.6	1.9	0.71	10500	7000
	Util	3.2	—	3.4	1.4	0.47	10500	7000
	Stud‡	4.7	—	5.3	1.4	0.47	10500	7000
Spruce-pine-fir	J & P*							
	Sel	8.0	6.2	8.8	1.8	0.68	10500	7000
	No. 1	5.6	4.3	7.9	1.8	0.68	9000	6000
	No. 2	5.6	4.3	6.9	1.6	0.68	9000	6000
	No. 3	4.1	—	5.3	1.2	0.45	9000	5500
	SLF†							
	Sel	9.1	7.1	8.8	1.8	0.68	10500	7000
	No. 1	6.4	4.9	7.9	1.8	0.68	9000	6000
	No. 2	6.4	4.9	6.9	1.6	0.68	9000	6000
	No. 3	4.7	—	5.3	1.2	0.45	9000	5500
	LF‡							
	Const	5.4	—	6.1	1.8	0.68	9000	6000
	Std	4.0	—	4.6	1.6	0.68	9000	6000
	Util	3.2	—	3.4	1.2	0.45	9000	6000
	Stud‡	4.7	—	5.3	1.2	0.45	9000	5500

*J & P. Joist and Plank grades: grading rules applicable to timber with cross-sectional dimensions greater than or equal to 38 mm X 114 mm.

†SLF. Structural Light Framing grades: stresses applicable to timber of 38 mm X 89 mm cross section; for other section sizes see table 14.

‡LF. Light Framing and Stud grades: stresses applicable to timber 38 mm X 89 mm cross section; for other section sizes see table 14.

§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 11. (concluded)

Standard name	Grade	Bending parallel to grain	Tension parallel to grain	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpen- dicular to grain §		Mean	Minimum
Sitka spruce	J & P*	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
	Sel	7.1	5.5	7.8	1.7	0.66	10000	6500
	No. 1	5.0	3.8	7.0	1.7	0.66	9000	6000
	No. 2	5.0	3.8	6.1	1.5	0.66	9000	6000
	No. 3	3.6	—	4.7	1.1	0.44	8500	5000
	SLF†							
	Sel	8.1	6.3	7.8	1.7	0.66	10000	6500
	No. 1	5.7	4.3	7.0	1.7	0.66	9000	6000
	No. 2	5.7	4.3	6.1	1.5	0.66	9000	6000
	No. 3	4.1	—	4.7	1.1	0.44	8500	5000
	LF‡							
	Const	4.8	—	5.4	1.7	0.66	8500	6000
	Std	3.5	—	4.0	1.5	0.66	8500	5500
	Util	2.8	—	3.0	1.1	0.44	8500	5500
	Stud‡	4.1	—	4.7	1.1	0.44	8500	5500

*J & P. Joist and Plank grades: grading rules applicable to timber with cross-sectional dimensions greater than or equal to 38 mm X 114 mm.

†SLF. Structural Light Framing grades: stresses applicable to timber of 38 mm X 89 mm cross section; for other section sizes see table 14.

‡LF. Light Framing and Stud grades: stresses applicable to timber 38 mm X 89 mm cross section; for other section sizes see table 14.

§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.

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Table 12. Grade stresses for USA softwoods: graded to NGRDL rules: for the dry exposure condition

NOTE. Bending and tension stresses for SLF, LF and Stud grades are applicable to depths or widths of 89 mm, see 14.6 and 16.2.

Standard name	Grade	Bending parallel to grain	Tension parallel to grain	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpen- dicular to grain §		Mean	Minimum
Douglas fir-larch	J & P*	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
	Sel	8.0	6.2	8.8	2.4	0.85	11000	8000
	No. 1	5.6	4.3	7.9	2.4	0.85	10000	6500
	No. 2	5.6	4.3	6.9	2.2	0.85	10000	6500
	No. 3	4.1	—	5.3	1.6	0.56	9500	6000
	SLF†							
	Sel	9.1	7.1	8.8	2.4	0.85	11000	8000
	No. 1	6.4	4.9	7.9	2.4	0.85	10000	6500
	No. 2	6.4	4.9	6.9	2.2	0.85	10000	6500
	No. 3	4.7	—	5.3	1.6	0.56	9500	6000
	LF‡							
	Const	5.4	—	6.1	2.4	0.85	10000	6500
	Std	4.0	—	4.6	2.2	0.85	9500	6500
	Util	3.2	—	3.4	1.6	0.56	9500	6500
	Stud‡	4.7	—	5.3	1.6	0.56	9500	6500
Hem-fir	J & P*							
	Sel	8.0	6.2	8.8	1.9	0.68	11000	8000
	No. 1	5.6	4.3	7.9	1.9	0.68	10000	6500
	No. 2	5.6	4.3	6.9	1.7	0.68	10000	6500
	No. 3	4.1	—	5.3	1.3	0.45	9500	6000
	SLF†							
	Sel	9.1	7.1	8.8	1.9	0.68	11000	8000
	No. 1	6.4	4.9	7.9	1.9	0.68	10000	6500
	No. 2	6.4	4.9	6.9	1.7	0.68	10000	6500
	No. 3	4.7	—	5.3	1.3	0.45	9500	6000
	LF†							
	Const	5.4	—	6.1	1.9	0.68	10000	6500
	Std	4.0	—	4.6	1.7	0.68	9500	6500
	Util	3.2	—	3.4	1.3	0.45	9500	6500
	Stud‡	4.7	—	5.3	1.3	0.45	9500	6500
Western whitewoods	J & P*							
	Sel	7.1	5.5	7.8	1.7	0.66	9000	6000
	No. 1	5.0	3.8	7.0	1.7	0.66	8000	5000
	No. 2	5.0	3.8	6.1	1.5	0.66	8000	5000
	No. 3	3.6	—	4.7	1.1	0.44	8000	4500
	SLF†							
	Sel	8.1	6.3	7.8	1.7	0.66	9000	6000
	No. 1	5.7	4.3	7.0	1.7	0.66	8000	5000
	No. 2	5.7	4.3	6.1	1.5	0.66	8000	5000
	No. 3	4.1	—	4.7	1.1	0.44	8000	4500
	LF‡							
	Const	4.8	—	5.4	1.7	0.66	8000	5000
	Std	3.5	—	4.0	1.5	0.66	8000	5000
	Util	2.8	—	3.0	1.1	0.44	8000	5000
	Stud‡	4.1	—	4.7	1.1	0.44	8000	5000
Southern pine	J & P*							
	Sel	10.3	8.0	11.3	2.5	0.98	12500	9000
	No. 1	7.2	5.5	10.2	2.5	0.98	11500	7500
	No. 2	7.2	5.5	8.9	2.2	0.98	11500	7500
	No. 3	5.3	—	6.8	1.7	0.64	11000	6500
	SLF†							
	Sel	11.7	9.1	11.3	2.5	0.98	12500	9000
	No. 1	8.2	6.3	10.2	2.5	0.98	11500	7500
	No. 2	8.2	6.3	8.9	2.2	0.98	11500	7500
	No. 3	6.0	0.0	6.8	1.7	0.64	11000	6500
	LF‡							
	Const	6.9	—	7.8	2.5	0.98	11000	7500
	Std	5.1	—	5.9	2.2	0.98	11000	7500
	Util	4.1	—	4.3	1.7	0.64	11000	7500
	Stud‡	6.0	—	6.8	1.7	0.64	11000	7000

*J & P. Joist and Plank grades: grading rules applicable to timber with cross-sectional dimensions greater than or equal to 38 mm X 114 mm.

†SLF. Structural Light Framing grades: stresses applicable to timber of 38 mm X 89 mm cross section; for other section sizes see table 14.

‡LF. Light Framing and Stud grades: stresses applicable to timber of 38 mm X 89 mm cross section; for other section sizes see table 14.

§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 to North American MSR rules*:
for the dry exposure condition**

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

Standard name	Grade	Bending parallel to grain	Tension parallel to grain	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpen- dicular to grain†		Mean	Minimum
Douglas fir-larch (USA and Canada)	900f-1.0E	5.9	3.5	6.8	2.6	1.19	6500	5000
	1200f-1.2E	7.9	4.7	7.7	2.6	1.19	8000	6500
	1450f-1.3E	9.5	5.7	8.5	2.6	1.19	9000	7000
	1650f-1.5E	10.8	6.5	9.0	2.6	1.19	10500	8500
	1800f-1.6E	11.8	7.1	9.3	3.0	1.19	11500	9000
	1950f-1.7E	12.8	7.7	9.6	3.0	1.19	12000	9500
	2100f-1.8E	13.8	8.3	10.1	3.0	1.19	13000	10500
Hem-fir (USA and Canada)	900f-1.0E	5.9	3.5	6.8	2.1	0.98	6500	5000
	1200f-1.2E	7.9	4.7	7.7	2.1	0.98	8000	6500
	1450f-1.3E	9.5	5.7	8.5	2.1	0.98	9000	7000
	1650f-1.5E	10.8	6.5	9.0	2.1	0.98	10500	8500
	1800f-1.6E	11.8	7.1	9.3	2.4	0.98	11500	9000
	1950f-1.7E	12.8	7.7	9.6	2.4	0.98	12000	9500
	2100f-1.8E	13.8	8.3	10.1	2.4	0.98	13000	10500
Spruce-pine-fir (Canada)	900f-1.0E	5.9	3.5	6.8	1.8	0.95	6500	5000
	1200f-1.2E	7.9	4.7	7.7	1.8	0.95	8000	6500
	1450f-1.3E	9.5	5.7	8.5	1.8	0.95	9000	7000
	1650f-1.5E	10.8	6.5	9.0	1.8	0.95	10500	8500
	1800f-1.6E	11.8	7.1	9.3	2.1	0.95	11500	9000
	1950f-1.7E	12.8	7.7	9.6	2.1	0.95	12000	9500
	2100f-1.8E	13.8	8.3	10.1	2.1	0.95	13000	10500
Southern pine (USA)	900f-1.0E	5.9	3.5	6.8	2.7	1.37	6500	5000
	1200f-1.2E	7.9	4.7	7.7	2.7	1.37	8000	6500
	1450f-1.3E	9.5	5.7	8.5	2.7	1.37	9000	7000
	1650f-1.3E	10.8	6.5	9.0	2.7	1.37	10500	8500
	1800f-1.6E	11.8	7.1	9.3	3.1	1.37	11500	9000
	1950f-1.7E	12.8	7.7	9.6	3.1	1.37	12000	9500
	2100f-1.8E	13.8	8.3	10.1	3.1	1.37	13000	10500

* Grading rules applicable to timber of the following dimensions:

38 mm X 63 mm, 38 mm X 72 mm, 38 mm X 89 mm, 38 mm X 114 mm, 38 mm X 140 mm, 38 mm X 184 mm,
38 mm X 235 mm, 38 mm X 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.

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Section size	Grade	Bending parallel to grain K_7	Tension parallel to grain K_{14}	Compression parallel to grain K_{10}	Modulus of elasticity K_{11}
mm 38 X 38	SLF				
	Sel	1.10	1.05	1.05	1.0
	No. 1	1.10	1.05	1.20	1.0
	No. 2	1.10	1.05	1.35	1.0
	No. 3	1.10	—	1.55	1.0
	LF				
	Const	0.90	—	1.0	1.0
	Std	0.75	—	1.0	1.0
	Util	0.50	—	0.65	1.0
	Stud	1.10	—	1.55	1.0
38 X 63	SLF				
	Sel	1.05	1.05	1.05	1.0
	No. 1	1.05	1.05	1.20	1.0
	No. 2	1.05	1.05	1.35	1.0
	No. 3	1.05	—	1.55	1.0
	LF				
	Const	0.80	—	1.0	1.0
	Std	0.95	—	1.0	1.0
	Util	0.60	—	0.75	1.0
	Stud	1.05	—	1.55	1.0
63 X 63	SLF				
	Sel	1.05	0.75	1.05	1.0
	No. 1	1.05	0.30	1.20	1.0
	No. 2	1.05	0.30	1.35	1.0
	No. 3	1.05	—	1.55	1.0
	LF				
	Const	0.80	—	1.0	1.0
	Std	0.95	—	1.0	1.0
	Util	0.60	—	0.75	1.0
	Stud	1.05	—	1.55	1.0
63 X 89 and 89 X 89	SLF				
	Sel	0.95	0.75	1.0	1.0
	No. 1	0.40	0.30	1.0	0.80
	No. 2	0.40	0.30	1.0	0.80
	No. 3	0.35	—	1.0	1.0
	Stud	0.35	—	1.0	1.0
38 X 114 and 38 X 140	Stud	0.95	—	1.05	1.0

NOTE. For grades and properties not listed, and for 38 mm X 89 mm cross sections, the modification factor has the value 1.0, i.e. no modification of the tabulated stresses is required.

Table 15. Grade stresses for tropical hardwoods graded to BS 5756 rules: for the dry exposure condition

Standard name	Grade	Bending parallel to grain*	Tension parallel to grain*	Compression		Shear parallel to grain	Modulus of elasticity	
				Parallel to grain	Perpendicular to grain†		Mean	Minimum
Balau	HS	N/mm ² 23.4	N/mm ² 14.1	N/mm ² 23.0	N/mm ² 5.3	N/mm ² 2.8	N/mm ² 20900	N/mm ² 16700
Ekki	HS	25.0	15.0	24.6	5.6	3.0	18500	15500
Greenheart	HS	26.1	15.6	23.7	5.9	2.6	21600	18000
Iroko	HS	12.6	7.5	12.6	2.8	1.6	10600	8500
Jarrah	HS	13.8	8.2	14.2	3.1	2.0	12400	8700
Kapur	HS	18.1	10.9	18.0	4.1	1.9	19200	15800
Karri	HS	17.1	10.3	15.2	3.9	1.7	17800	13500
Kempas	HS	19.3	11.6	19.4	4.3	2.3	19100	16000
Keruing	HS	16.2	9.7	16.0	3.6	1.7	19300	16100
Merbau	HS	18.1	10.9	15.7	4.1	2.3	15900	11700
Opepe	HS	17.0	10.2	17.6	3.8	2.1	14500	11300
Teak	HS	13.7	8.2	13.4	3.1	1.7	10700	7400

*Stresses applicable to timber 300 mm deep (or wide); for other section sizes see 14.6 and 16.2.

†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 16. Modification factor K_2 by which dry stresses and moduli should be multiplied to obtain wet stresses and moduli applicable to wet exposure conditions

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

11 Additional properties

In the absence of specific test data it is recommended that, for tension perpendicular to the grain, torsional shear and rolling shear, values which are one-third of those for shear parallel to the grain should be used.

For modulus of elasticity perpendicular to the grain a value of one-twentieth (i.e. 0.05) of the permissible modulus of elasticity should be used.

For shear modulus a value of one-sixteenth (i.e. 0.0625) of the permissible modulus of elasticity should be used.

Where the direction of the load is inclined to the grain by an angle α , the permissible compression stress for the inclined surface is given by 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 parallel and perpendicular to the grain stresses respectively, modified as appropriate for moisture content, section size and/or duration of load (see 10.2 and clause 12).

12 Duration of load

The stresses given in tables 9, 10, 11, 12, 13 and 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 advantage is taken of this clause to use a modification factor K_3 greater than unity, the design should be checked to ensure that the permissible stresses are not exceeded for any other condition of loading that might be relevant. This modification factor is applicable to all strength properties but is not applicable to moduli of elasticity or to shear moduli.

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

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Table 17. Modification factor K_3 for duration of loading

Duration of loading	Value of K_3
Long term (e.g. dead + permanent imposed*)	1.00
Medium term (e.g. dead + snow, dead + temporary imposed)	1.25
Short term (e.g. dead + imposed + wind†, dead + imposed + snow + wind†)	1.50
Very short term (e.g. dead + imposed + wind‡)	1.75
*For uniformly distributed imposed floor loads $K_3 = 1$ except for type 2 and type 3 buildings in table 5 of BS 6399 : Part 1 : 1984 where, for corridors, hallways, landings and stairways only, K_3 may be assumed to be 1.5. †For wind, short term category applies to class C (15 s gust) as defined in CP 3 : Chapter V : Part 2. ‡For wind, very short term category applies to classes A and B (3 s or 5 s gust) as defined in CP 3 : Chapter V : Part 2.	

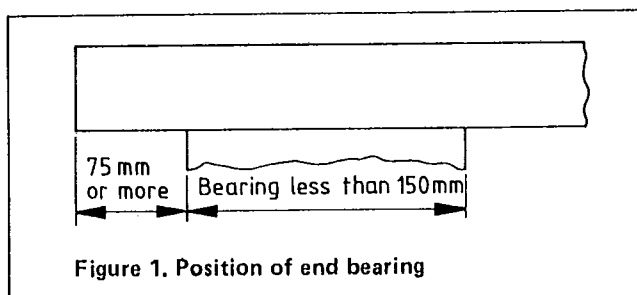
in 10.2, clauses 12 and 13 and by the additional factors given in this clause. They should be taken as the product of the grade stress given in clause 10 and the appropriate modification factors.

14.2 Length and position of bearing

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.

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.

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



13 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 14.10, 14.11 and section three respectively.

The provisions of this clause do not extend to the calculation of modification factor K_{12} (given in table 22 and appendix C) for load-sharing columns.

Table 18. Modification factor K_4 for bearing stress

Length of bearing* (in mm)	10	15	25	40	50	75	100	150 or more
Value of K_4	1.74	1.67	1.53	1.33	1.20	1.14	1.10	1.00
*Interpolation is permitted.								

14.3 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 could be adequate according to this Part of BS 5268. Where advantage is taken of this clause due attention should be paid to the eccentricity of the load on the supporting structure.

14.4 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.

14 Flexural members

14.1 General.

Permissible stresses for timber flexural members are governed by the particular conditions of service and loading as given

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_s , where:

(a) for a notch on the top edge (see figure 2(a)),

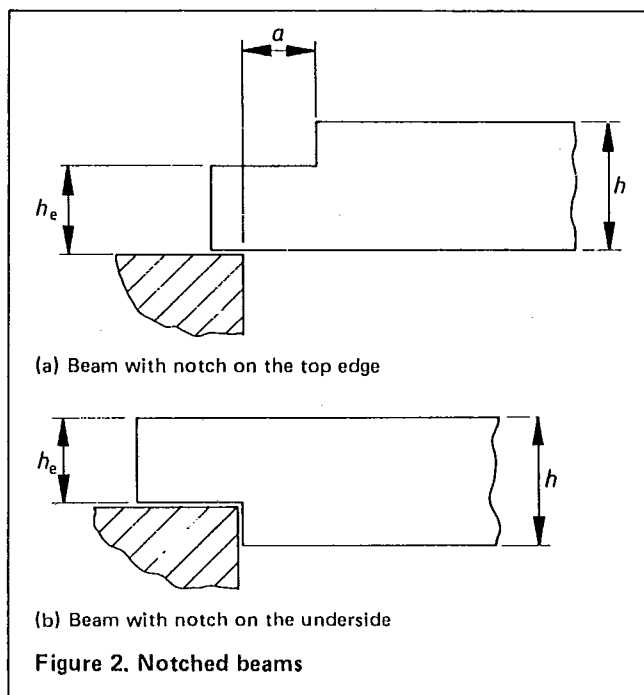
$$K_s = \frac{h(h_e - a) + ah_e}{h_e^2} \text{ for } a \leq h_e$$

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

(b) for a notch on the underside (see figure 2(b)),

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

where h is the total depth of the beam and a is as shown in figure 2. The effective depth, h_e , should be not less than $0.5h$.



14.5 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

14.6 Depth factor

The grade bending stresses given in table 9 apply to material assigned to a strength class and having a depth, h (measured in millimetres), of 300 mm.

The grade bending stresses given in tables 10, 11, 12, 13 and 15 apply, as appropriate to:

- (a) solid timber graded in accordance with BS 4978 or BS 5756 and having a depth, h , of 300 mm;
- (b) solid timber graded to the NLGA or NGRDL Structural Light Framing, Light Framing or Stud rules and having a depth, h , of 89 mm;
- (c) solid timber graded to the North American MSR rules having the particular depth quoted;
- (d) solid timber graded to the NLGA or NGRDL Joist and Plank rules and having a depth, h , of 300 mm;
- (e) all thicknesses of laminations graded in accordance with BS 4978 or BS 5756.

For other depths of beams assigned to a strength class or graded to BS 4978, BS 5756 or NLGA and NGRDL Joist and Plank rules, the grade bending stresses should be multiplied by the depth modification factor K_7 , where:

$K_7 = 1.17$ for solid timber beams having a depth of 72 mm or less;

$K_7 = (300/h)^{0.11}$ for solid and glued laminated beams having a depth greater than 72 mm and less than 300 mm;

$K_7 = 0.81 \frac{(h^2 + 92300)}{(h^2 + 56800)}$ for solid and glued laminated beams having a depth greater than 300 mm.

For other depths of solid timber beams graded to North American Structural Light Framing, Light Framing and Stud rules and not assigned to a strength class, the grade stresses should be multiplied by the modification factor K_7 appropriate to their cross-sectional sizes and given in table 14.

For solid timber beams graded in accordance with the North American NLGA or NGRDL rules and not assigned to a strength class, the grade moduli of elasticity should be multiplied by the modification factor K_{11} appropriate to their cross-sectional sizes and given in table 14. For North American grades not listed in table 14 and for Structural Light Framing, Light Framing and Stud 38 mm x 89 mm and all Joist and Plank grades and sizes, the modification factor K_{11} has the value of 1.0.

14.7 Deflection and stiffness

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

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

For most general purposes, including domestic flooring, 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 longer span domestic floor

*Unlike the values given in CP 112 : Part 2 the modulus of elasticity values tabulated in this Part of BS 5268 do not include an element due to shear.

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joists it is further recommended that, to avoid undue vibration resulting from moving or impact loading, the deflections under design load should not exceed 14 mm.

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 clause 13, 14.10 and 14.11 respectively.

14.8 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 6 times the depth	6
Ends held in position and both edges held firmly in line	7

14.9 Notched 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 diameters 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.

14.10 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 may be 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 to 1 and 10 to 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 to 1 and 20 to 1, the beam should be held in line at the ends;
- (d) if the ratio of the second moments of area is between 20 to 1 and 30 to 1, one edge should be held in line;
- (e) if the ratio of the second moments of area is between 30 to 1 and 40 to 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 to 1, the compression flanges should be fully restrained.

The modification factors K_{27} , K_{28} and K_{29} given in table 26 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 factor (K_{27} , K_{28} , K_{29}) for that flange. The total number of pieces of timber in both flanges should be taken as the number of laminations 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.

14.11 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 given in table 20 should be used for the calculation of deflections.

Table 20. Modification factor K_9 to minimum modulus of elasticity for trimmer joists and lintels		
Number of pieces	Values 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

15 Compression members

15.1 General

The limitations on bow in most stress grading rules are inadequate for the selection of material for columns. Particular attention should therefore be paid to the straightness of columns, e.g. by limiting bow 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 10.2, clauses 12 and 13, and by the additional factors given in this clause.

15.2 Size factors

The grade compression stresses given in tables 9, 10 and 15 apply to all solid timber members and laminations graded in accordance with BS 4978 or BS 5756.

For solid timber members graded in accordance with the North American NLGA or NGRDL rules and not assigned to a strength class, the grade compression stresses given in tables 11, 12 and 13 should be multiplied by the modification factors K_{10} appropriate to their cross-sectional sizes, and given in table 14. Similarly, for buckling calculations (see 15.5 and 15.6), the grade moduli of elasticity values should be multiplied by the modification factor K_{11} given in table 14.

For North American grades and sizes not listed in table 14 and for Structural Light Framing, Light Framing and Stud 38 mm x 89 mm and all Joist and Plank grades and sizes the modification factors K_{10} and K_{11} have the value of 1.0.

15.3 Effective length

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

- (a) table 21 for the particular end conditions; or
- (b) the deflected form of the compression member as affected by any restraint and/or fixing moment(s), the effective length being the distance between adjacent points of zero bending between which the member is in single curvature.

Table 21. Effective length of compression members

End conditions	Effective length Actual length L_e/L
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

15.4 Slenderness ratio

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

The slenderness ratio should not exceed 180 for:

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

The slenderness ratio should not exceed 250 for:

- (c) any member normally subject to tension or combined tension and bending arising from dead and imposed loads, but subject to a reversal of axial stress solely from the effect of wind;
- (d) any compression member carrying self weight and wind loads only (e.g. wind bracing).

15.5 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 size,

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moisture content, duration of load and load sharing (see 15.2 and clauses 10, 12 and 13).

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 size, moisture content, duration of load and load sharing, and the modification factor K_{12} given in table 22, or calculated using the equation given in appendix C.

The value of modulus of elasticity required for entry to table 22 or the equation in appendix C 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 26). For horizontally laminated members, the modified mean modulus of elasticity should be used (see clauses 22 and 18). The compression parallel to the grain stress σ_c required for entry to table 22 or the equation in appendix C should be the grade stress modified only for moisture content, duration of load, and size where applicable (see table 14).

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 $E/\sigma_{c,||}$, required for entry to table 22 or the equation in appendix C, the modulus of elasticity is constant for all load durations, whereas the compression stress should be modified for duration of load (clause 12).

15.6 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:

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

where

- $\sigma_{m,a,||}$ is the applied bending stress;
- $\sigma_{m,adm,||}$ is the permissible bending stress;
- $\sigma_{c,a,||}$ is the applied compression stress;
- $\sigma_{c,adm,||}$ is the permissible compression stress (including K_{12});
- σ_e is the Euler critical stress $\pi^2 E/(L_e/i)^2$; utilizing the modulus of elasticity given in 15.5.

The effective length of a member subject to axial compression and bending should be that given in 15.3(b).

For members in load-sharing systems (see clause 13), the permissible bending stress, $\sigma_{m,adm,||}$, and the permissible compression stress, $\sigma_{c,adm,||}$, 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

$E/\sigma_{c, }$	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
1000	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
1100	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
1200	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
1300	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
1400	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
1500	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
1600	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
1700	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
1800	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
1900	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
2000	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

15.7 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.

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.

15.8 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 15.9 and section six.

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.

15.9 Packs for spaced columns

15.9.1 End packs

15.9.1.1 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 cross section area of the column;
- b is the breadth 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.

15.9.1.2 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.

15.9.2 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 15.9.1.1).

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 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.

15.10 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 XX and YY as indicated in figure 3.

The effective length of the column, for buckling about the XX or YY axes, should be assessed in accordance with the requirements of table 21.

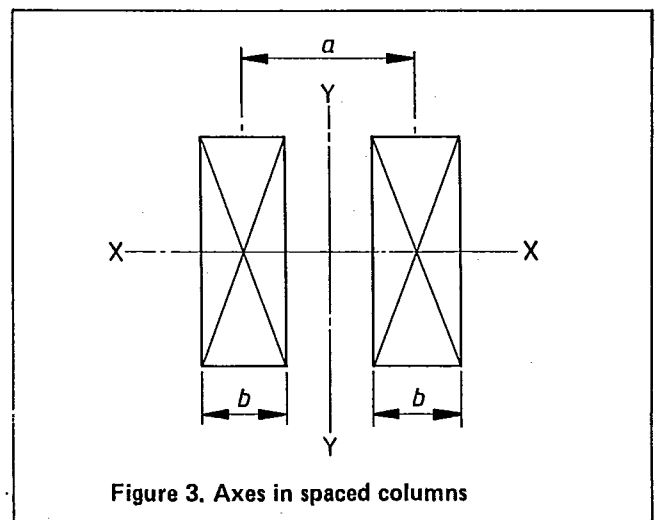


Figure 3. Axes in spaced columns

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

- (a) that for a solid column (whose area is that of the area of the timber) bending about axis XX;
- (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 YY axis 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.

15.11 Compression members in triangulated frameworks

Compression members in triangulated frameworks such as trusses and girders (but excluding trussed rafters designed in

BS 5268 : Part 2 : 1988
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Method of connection	Values of K_{13} for values of the ratio of space to thickness of the thinner member of			
	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

accordance with Part 3 of this standard) should be designed in accordance with the previous clauses subject to the following.

- (a) With continuous compression members, the effective length for the purpose of determining the slenderness ratio may be taken as between 0.85 and 1.0 (depending upon the degree of fixity and the distribution of load between node points) times the distance between the node points of the framework for buckling in the plane of the framework, and times the actual distance between effective lateral restraints for buckling perpendicular to the plane of the framework. With roof trusses, e.g., purlins or tiling battens may be taken as providing effective lateral restraints, provided they are adequately fastened to the top chord and are carried back to effective bracing or other support. With roofs employing rafters adequately fastened to, e.g. a boarded or wood-wool covering, it can be taken that effective lateral restraint is provided along the whole length of the rafter.
- (b) With non-continuous compression members, such as web members in a framework, the effective length for buckling depends on the type of connection at the ends of the members and may be calculated using the appropriate end fixity (see table 21).

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

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

- (c) The recommendations in the first sentences of 15.9.1.1 and 15.9.2 do not apply to spaced compression members in triangulated frameworks. Intermediate packings should be not less than 200 mm long and fixed in such a manner as to transmit a tensile force parallel to axis XX, between the individual members, of not less than 2.5 % of the total axial force in the spaced compression member.

16 Tension members**16.1 General**

Permissible stresses for timber tension members are governed by the particular conditions of service and loading as given in 10.2, clauses 12 and 13 and by the additional factors given in this clause. They should be determined as the product of the grade stress and the appropriate modification factors.

16.2 Width factor

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

The grade tension stresses given in tables 10, 11, 12, 13 and 15 apply, as appropriate, to:

- solid timber graded in accordance with BS 4978 or BS 5756, and having a width, h , of 300 mm;
- solid timber graded to the NLGA or NGRDL Structural Light Framing, Select Structural, No. 1 and No. 2 grades and having a width, h , of 89 mm;
- solid timber graded to the North American MSR rules having the particular width quoted;
- solid timber graded to the NLGA or NGRDL Joist and Plank, Select Structural, No. 1 and No. 2 grades and having a width, h , of 300 mm;
- laminations graded in accordance with BS 4978 or BS 5756.

For other widths of members assigned to a strength class or graded to BS 4978, BS 5756, NLGA or NGRDL Joist and Plank rules, the grade tension stresses should be multiplied by the width modification factor K_{14} , where

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

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

For other widths of solid timber members graded to the North American Structural Light Framing rules and not assigned to a strength class, the grade stresses should be multiplied by the modification factor K_{14} appropriate to their cross-sectional sizes, given in table 12.

Note that Light Framing and Stud grades, Structural Light Framing No. 3 and Joist and Plank No. 3 grade should not be used for tension members.

16.3 Members subject to axial tension and bending

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

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

where

- $\sigma_{m,a,||}$ is the applied bending stress;
 $\sigma_{m,adm,||}$ is the permissible bending stress;
 $\sigma_{t,a,||}$ is the applied tension stress;
 $\sigma_{t,adm,||}$ is the permissible tension stress.

Section three. Glued laminated timber

17 General

Glued laminated timber should be manufactured in accordance with BS 4169 and clause 20.

All timber used for laminated softwood members should be stress graded in accordance with BS 4978. All timber used for laminated hardwood beams, should be stress graded in accordance with BS 5756. The stresses given in this Part of BS 5268 apply only to timber graded in accordance with BS 4978 and BS 5756.

18 Grade stresses for horizontally glued laminated members

The grade stresses for a horizontally glued laminated softwood member should be taken as the products of the SS grade stresses for the species and the modification factors from tables 24 and 25 appropriate to the grade or grades of timber used for the laminations. Table 24 applies to members horizontally laminated from one grade of timber. Table 25 applies to members horizontally laminated from more than one grade of timber and fabricated so that not less than 25 % of the depth at both the top and bottom of the member, is of the superior grade.

For horizontally glued laminated hardwood members, the HS grade stress for the species should be multiplied by the LB grade modification factors given in table 24.

The modification factors given in tables 24 and 25 apply to members having 4 or more laminations, all of similar thickness.

19 Grade stresses for vertically glued laminated beams

Permissible stresses for vertically glued laminated beams are governed by the particular conditions of service and loading given in 10.2, clauses 12 and 13 and by the modification factors K_{27} , K_{28} and K_{29} given in table 26 appropriate to the number of laminations.

The modification factors given in table 26 apply to softwood and hardwood graded to the structural timber grades and not to the laminating grades.

20 Glued end joints in glued laminated timber

The end joints in LB and LC laminations should have bending efficiency ratings (regardless of the type of loading) of at least 70 % and 55 % respectively. Where this recommendation is not met, and for LA laminations in a horizontally glued laminated softwood member, the maximum bending, tension or compression parallel to the grain stress to which a glued end joint in any individual lamination is subjected should not exceed the value obtained by multiplying the SS grade stress for the particular species by the efficiency rating for the joint (see appendix F), by the appropriate modification factors for size of member, moisture content and duration of load, and also by modification factor K_{30} , K_{31} or K_{32} from table 27, as appropriate to the type of loading.

For a horizontally glued laminated hardwood member,

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

Grade	Number of laminations*	Bending parallel to the grain K_{15}	Tension parallel to the grain K_{16}	Compression parallel to the grain K_{17}	Compression perpendicular to the grain K_{18}	Shear parallel to the grain K_{19}	Modulus of elasticity $K_{20}^\dagger$
LA	4 or more	1.85	1.85	1.15	1.33	2.00	1.00
LB	4	1.26	1.26	1.04	1.33	2.00	0.90
	5	1.34	1.34				
	7	1.39	1.39				
	10	1.43	1.43				
	15	1.48	1.48				
	20 or more	1.52	1.52				
LC	4	0.74	0.74	0.92	1.33	2.00	0.80
	5	0.82	0.82				
	7	0.91	0.91				
	10	0.98	0.98				
	15	1.05	1.05				
	20 or more	1.11	1.11				

*Interpolation is permitted for intermediate numbers of laminations.

$^\dagger K_{20}$ should be applied to the SS grade mean modulus of elasticity for softwood species and to the HS grade mean modulus of elasticity for hardwood species.

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the maximum bending, tension or compression parallel to the grain stress to which a glued end joint in any individual lamination is subjected should not exceed the value obtained by multiplying the HS grade stress for the particular species by the efficiency rating for the joint, by the appropriate modification factors for size of member, moisture content and duration of load, and also by modification factor K_{30} , K_{31} or K_{32} , as appropriate to the type of loading, from table 27. The joint efficiency ratings for hardwoods should be determined by test.

For a vertically glued laminated beam, glued end joints should have an efficiency of not less than that required for

the strength class or species and grade of timber (see appendix F and table 88) unless the permissible stress is reduced accordingly.

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

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

Table 25. Modification factors K_{21} , K_{22} , K_{23} , K_{24} , K_{25} and K_{26} for combined grade glued laminated members and horizontally glued laminated beams

Grade combination	Number of laminations*	Bending parallel to the grain K_{21}	Tension parallel to the grain K_{22}	Compression parallel to the grain K_{23}	Compression perpendicular to the grain K_{24}	Shear parallel to the grain K_{25}	Modulus of elasticity $K_{26}^{\dagger}$
LA/LB/LA	4 or more	1.76	1.76	1.09	1.33	2.00	0.93
LB/LC/LB	4	1.26	1.26	0.97	1.33	2.00	0.85
	8	1.32	1.32				
	12	1.37	1.37				
	16	1.41	1.41				
	20 or more	1.45	1.45				

* Interpolation is permitted for intermediate numbers of laminations.

$\dagger K_{26}$ should be applied to the SS grade mean modulus of elasticity for softwood species.

Table 26. Modification factors K_{27} , K_{28} and K_{29} for vertically glued laminated members

Number of laminations	Bending, tension and shear parallel to grain K_{27}		Modulus of elasticity, compression parallel to grain K_{28}^*		Compression perpendicular to grain $K_{29}^{\dagger}$
	Softwoods	Hardwoods	Softwoods	Hardwoods	Softwoods and hardwoods
2	1.11	1.06	1.14	1.06	1.10
3	1.16	1.08	1.21	1.08	
4	1.19	1.10	1.24	1.10	
5	1.21	1.11	1.27	1.11	
6	1.23	1.12	1.29	1.12	
7	1.24	1.12	1.30	1.12	
8 or more	1.25	1.13	1.32	1.13	

* When applied to the value of the modulus of elasticity E , K_{28} is applicable to the minimum value of E .

$\dagger$ If no wane is present, K_{29} should have the value 1.33 and, regardless of the grade of timber used, should be applied to the SS or HS grade stress for the species.

Table 27. Modification factors K_{30} , K_{31} and K_{32} for individually designed glued end joints in horizontally glued laminated members

	Bending parallel to the grain K_{30}	Tension parallel to the grain K_{31}	Compression parallel to the grain K_{32}
Softwoods	1.85	1.85	1.15
Hardwoods	1.50	1.50	1.14

21 Glued laminated flexural members

21.1 General

The permissible stresses for glued laminated timber flexural members are governed by the particular conditions of service and loading as given in 10.2, clauses 12 and 13, by the modification factors for flexural timber members given in clause 14 and by the additional factors given in this clause.

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

21.2 Camber

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

21.3 Curved glued laminated beams

21.3.1 General. For curved glued laminated beams with constant rectangular cross section (see figure 4) the ratio of the radius of curvature, r , to the lamination thickness, t , should be greater than 125 for softwoods or 100 for hardwoods.

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

$$K_{33} = 0.76 + 0.001 \frac{r}{t} \quad \text{and}$$

$$K_{33} \leq 1.0$$

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

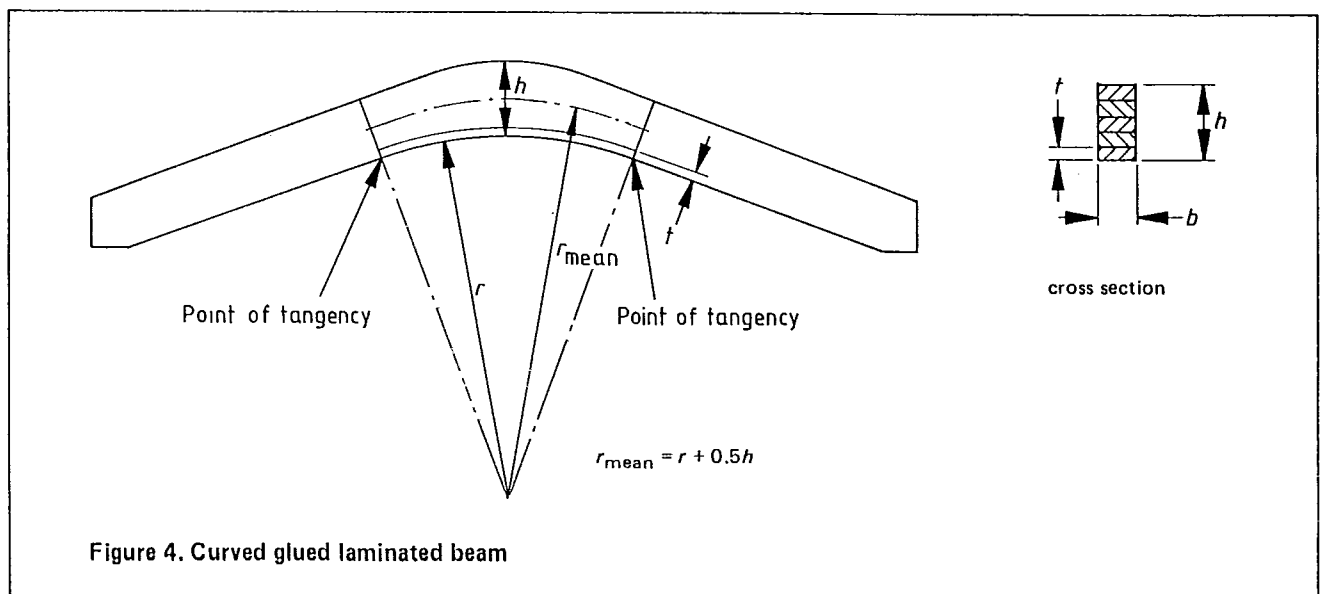
(a) bending stress in the extreme fibre on the concave face, $\sigma_m = K_{34} \frac{6M}{bh^2}$

where

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

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

(b) bending stress in the extreme fibre on the convex face, $\sigma_m = \frac{6M}{bh^2}$



*Unlike the values given in CP 112 : Part 2, the modulus of elasticity values tabulated in this Part of BS 5268 do not include an element due to shear.

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21.3.3 Radial stresses. The radial stress, σ_r , induced by a bending moment, M , in a curved glued laminated beam of constant rectangular cross section should be calculated as:

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

Where the moment tends to increase the radius of curvature of the beam, the radial stress will be tension perpendicular to the grain and the value of σ_r should be not greater than one-third of the appropriate permissible shear parallel to the grain stress.

Where the moment tends to reduce the radius of curvature, the radial stress will be compression perpendicular to the grain and the value of σ_r should be not greater than 1.33 times the SS grade compression perpendicular to the grain stress appropriate to the species.

21.4 Pitched cambered softwood beams

21.4.1 Bending stress. For pitched cambered beams of rectangular cross section whose geometry and loading are symmetrical about the mid-span (see figure 5), the bending stress at the apex is maximum at the soffit and should be calculated from:

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

where

α is the slope of the upper surface of the beam;

M_{apex} is the bending moment at the apex;

h_{apex} is the depth of the section at the apex.

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

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

where

M_{tang} is the bending moment at the point of tangency;

h_{tang} is the depth of the section at the point of tangency.

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

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

$$(a) \sigma_r = K_{35} \frac{6M_{\text{apex}}}{bh_{\text{apex}}^2}$$

or

$$(b) \sigma_r = \frac{3M_{\text{apex}}}{2r bh_{\text{apex}}}$$

where

σ_r is the radial stress perpendicular to the grain;

M_{apex} is the bending moment at the apex;

r is the radius of curvature at the centre line of the depth of the apex;

b is the breadth of the section;

h_{apex} is the total depth of the section at the apex;

K_{35} is a stress modification factor given by

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

and C are constants having the values given in table 28.

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

Table 28. Values of constants for determining radial stresses in pitched cambered softwood beams

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

*Slope measured in degrees from the horizontal (see figure 5).

The radial stresses at the tangent points should be calculated in accordance with 21.3.3.

The radial stress σ_r should be not greater than one-third of the appropriate permissible stress in shear parallel to the grain.