



Timber structures

Part 1: Design methods



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- Australian Building Codes Board
- Australian Timber Importers' Federation
- Australian Wood Panels Association
- BRANZ
- CSIRO Manufacturing and Materials Technology
- Curtin University of Technology
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- New Zealand Timber Industry Federation
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- University of Auckland
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- Wood Processors Association

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Australian Standard[®]

Timber structures

Part 1: Design methods

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee TM-001, Timber Structures, to supersede AS 1720.1—1997.

This Standard incorporates Amendment No. 1 (December 2010), Amendment No. 2 (August 2011) and Amendment No. 3 (August 2015). The changes required by the Amendments are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The decision to prepare this Standard as an Australian Standard was by consensus agreement of the Joint Committee.

The objective of this Standard is to provide a code of practice for the design and acceptance of timber structures and elements. It includes design methods and design data appropriate for commonly encountered structural elements and materials and requirements to be met for specification of the design, installation and maintenance of timber structures.

Capacity factors for the timber materials represented in this Standard have been reviewed and, in some cases, modified to better reflect the safety levels appropriate for the wide range of applications for which timber structural elements may be used.

For housing, the increasing sizes of houses and increasingly larger areas that are in some cases supported by a single structural element has resulted in a need to limit application of category 1 capacity factors according to the area likely to be affected by failure of the individual element. For structures other than houses the definition of ‘primary structural element’ has been changed to recognise that even a partial structural collapse of some structures can have severe consequences.

Conceptually, the limit state design principles of this Standard do not differ from the 1997 version. Only essential changes and editorial improvements have been made, which reflect experience with the application of the Standard over the past decade; these changes relate to layout improvements and clarification of meaning.

Differences from the 1997 edition include the following:

- (a) The notation and terminology for actions have been aligned with AS/NZS 1170 series.
- (b) For easier referencing, the design properties for commonly available structural sawn timber (F-grades, MGP-grades and A17-grade) are now consolidated and presented together in an appendix.
- (c) The presentation of requirements for selection of capacity factors for member and joint design has been simplified and clarified.
- (d) For consistency with the AS/NZS 4063 series, characteristic properties are now uniformly defined as including the effect of size.
- (e) Issues associated with evaluation methods, verification procedures, monitoring and quality control in production and manufacture are not relevant to design and are not therefore directly referred to in this revised Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard Timber structures

Part 1: Design methods

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE AND APPLICATION

1.1.1 Scope

This Standard sets out limit state design methods for the structural use of timber, which are based on the principles of structural mechanics and on data established by research. It provides design data for sawn timber, laminated timber, timber in pole form, plywood, laminated veneer lumber and various types of fastenings. In addition, it provides methods of test for components or assemblies of unconventional design which may not be readily amenable to detailed analysis.

For ease of use, the simpler design situations are set in the main body of the text. Related appendices, which form an integral part of the Standard, give acceptable procedures for detailed design situations.

1.1.2 Application

This Standard is intended for use in the design or appraisal of structural elements or systems comprised of timber or wood products and of structures comprised substantially of timber.

1.2 NORMATIVE REFERENCES

The normative documents referenced in this Standard are listed in Appendix A.

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

1.3 TIMBER

1.3.1 General

All timber used in accordance with this Standard shall comply with the requirements of the appropriate Australian Standards, as follows:

- (a) *Visually graded sawn timber* Visually graded sawn timber shall conform to the requirements of AS 2082 or AS 2858.
- (b) *Mechanically graded timber* Mechanically graded timber shall conform to the requirements of AS/NZS 1748.
- (c) *Proof-graded timber* Proof-graded timber shall conform to the requirements of AS 3519.
- (d) *Structural plywood* Structural plywood shall conform to the requirements of AS/NZS 2269.0.
- (e) *Structural laminated veneer lumber* Structural laminated veneer lumber shall conform to the requirements of AS/NZS 4357.0.
- (f) *Glued laminated timber* Glued laminated timber shall conform to the requirements of AS/NZS 1328.1

- (g) *Round timber* Round timber shall conform to the requirements of AS 3818.3 or AS 3818.11, as appropriate.
- (h) *Other timber products or grades* Timber products or grades not listed in this Standard may have properties established by testing and evaluation methods consistent with those described in the AS/NZS 4063 series. In addition, for other timber-based products, modification factors for duration of load effect for strength and stiffness shall be determined based on authoritative research. Consideration shall also be given to the determination of the structural durability of adhesives used for manufacture.

1.3.2 Identification

Structural timber used in conjunction with this Standard shall have its stress grade identified in accordance with the relevant Australian timber product Standard given in Clause 1.3.1.

For various purposes, it may also be necessary to specify a particular species. When a particular species is specified, the specification shall require that all pieces of timber be suitably identified as to species.

NOTES:

- 1 The design properties recommended in this Standard have been chosen on the assumption that structures of unseasoned timber that are allowed to dry will not receive their full design load until a period of air-drying of at least 2 weeks has taken place. Freshly sawn timber that is unseasoned, or has recently been treated with waterborne chemicals, tends to have a reduced resistance and stiffness to sustained loads during the initial drying period. Under normal circumstances, unseasoned timber will have had this drying period before being subjected to its full design load.
- 2 Usually, only a limited number of the timber species and stress grades listed in this Standard will be readily available at any particular place and time.

1.3.3 Change of grade

The strength properties of graded timber or timber products may alter as a consequence of subsequent processes such as longitudinal resawing, chemical treatments and redrying processes.

NOTE: It may be necessary to reassess strength properties to ensure that graded timber or timber products still satisfy design requirements after having been subjected to such processes.

1.3.4 Special provisions

Design loads for timber joints and design rules for notched beams given herein are based on the assumption that there are no loose knots, severe sloping grain, gum veins, gum or rot pockets, lyctid-susceptible sapwood, holes or splits in the vicinity of any fasteners or notch roots.

1.3.5 Treated timber

Timber, treated by impregnation with waterborne chemicals such as preservatives, is classified as unseasoned timber unless seasoning is specified.

NOTE: Where the material is dried after treatment, re-grading may be required.

1.4 GENERAL DESIGN CONSIDERATIONS

1.4.1 Loads

1.4.1.1 General

A structure and its structural elements shall be designed to resist the design action effects produced by—

- (a) the combinations of actions for the strength, stability and serviceability limit states as specified in AS/NZS 1170.0; or

- (b) such other design actions deemed to be acceptable for the limit state as appropriate to the intended end-use service conditions of a structure or its structural elements.

1.4.1.2 *Duration of load*

Duration of load effects need to be considered in the determination of the critical combination of actions.

NOTE: For definition of duration of loading, see Clause 1.7.2.12, and for further information, see Clause 2.4.1.

1.4.2 **Design methods**

1.4.2.1 *General*

A structure and its structural elements shall be designed to resist the design action effects resulting from the appropriate combinations of actions in order to satisfy the requirements for strength, stability and serviceability limit states.

1.4.2.2 *Strength limit state*

This limit state condition shall be deemed to be satisfied when the structural elements of a structure are proportioned so that their design capacities (R_d) equal or exceed the design action effects (S^*). For a given failure mode the strength limit state takes the general form—

$$R_d \geq S^*$$

where

R_d = design capacity of a structural element determined in accordance with the relevant Sections of this Standard.

NOTE: The general requirements are given in Section 2.

S^* = design action effect, such as bending moment, axial force or shear force resulting from the combinations of actions for the strength limit states

NOTE: The design capacity (R_d) of a structural element is also referred to as the factored resistance of the structural element for a given failure mode.

1.4.2.3 *Stability limit state*

The structure as a whole (or any part of it) shall be designed to prevent instability due to overturning, uplift or sliding as follows:

- (a) The design action effect and the design resistance effect shall be determined in accordance with AS/NZS 1170.0.
- (b) The whole or part of the structure shall be proportioned so that the design resistance effect is not less than the design action effect.

1.4.2.4 *Serviceability limit state*

The structure and its structural elements shall be designed to give satisfactory performance under the specified service conditions by controlling or limiting deflections, vibration and displacement of fasteners as follows:

- (a) Unless otherwise agreed, the combinations of actions for serviceability limit states shall be in accordance with AS/NZS 1170.0.
- (b) Deflections due to combinations of actions appropriate for the serviceability limit state shall be determined by elastic analysis methods.

NOTES:

- 1 The deflection limits for the serviceability limit state should be appropriate to the structure and its intended use, the nature of loading, the relationship between adjacent members and the effect on other elements supported.
- 2 Guidance on selection of deflection limits is given in Appendix B.

- 3 The determination of acceptable deflection limits is part of the design process performed by the design engineer.
 - 4 The characteristic modulus of elasticity values given in this Standard are mean values only and, accordingly, deflection of individual members subjected to the design loads may vary both above and below the calculated estimate. Where the actual deflection is critical, it is suggested that lower fifth-percentile estimates of modulus of elasticity should be obtained and used. A procedure for estimating lower fifth-percentile values of modulus of elasticity is given in Appendix B.
- (c) Where required, structures shall be designed to ensure that the vibration induced by machinery, or vehicular or pedestrian traffic does not adversely affect the serviceability of the structure.
- NOTES:
- 1 Where there is likelihood of a structure being subjected to vibration effects, measures should be taken to minimize any dynamic behaviour so as to prevent possible discomfort or alarm, damage to the structure, or interference with its proper function.
 - 2 The AS 2670 series gives guidance on the evaluation of human exposure to whole-body vibrations of the type likely to be transmitted by structures.
- (d) Where required, the displacement associated with various types of fasteners shall be assessed in accordance with the methods given in Appendix C.

1.4.2.5 *Experimentally based design*

Where a structure or a structural element is demonstrated by the full-scale tests specified in Appendix D to satisfy requirements for strength, deformation, stability and serviceability, the corresponding design requirements of this Standard shall also be deemed to have been satisfied.

NOTE: Other design considerations will still be required to be met.

1.4.3 Timber dimensions for engineering calculations

All engineering calculations shall be based on the minimum cross-section after taking account of tolerances. Such calculations shall not be based on the nominal cross-section.

NOTE: Nominal cross-section is sometimes referred to as 'called' cross-section.

1.4.4 Other design considerations

1.4.4.1 *Buckling restraints*

Where there is some doubt as to the effectiveness of buckling restraints, appropriate computations, as given in Appendix E, shall be made to check the stiffness and strength of the restraints.

1.4.4.2 *Erection and other extraneous forces*

Adequate provision shall be made to resist the lateral and other forces that can occur during the transport of structural elements, and during the erection of a structure.

1.4.4.3 *Secondary stresses*

Careful consideration shall be given to the influence of secondary stresses. Where secondary stresses cannot be reduced to negligible proportions, suitable provisions in the design or some reduction in permissible primary stresses shall be made.

1.4.4.4 Shrinkage

When using unseasoned timber, consideration shall be given to the effects of shrinkage. Detailing of the joints shall not restrain shrinkage where splitting could render the joint ineffective. Consideration shall also be given to detailing to avoid damage or unsightly appearances.

NOTE: For most timbers the magnitude of shrinkage is in the range of 0.1% to 0.3% in the direction of the wood grain and 2% to 10% transverse to this direction. Information on shrinkage for specific species can be obtained from the following:

- (a) KINGSTON, R.S.T. and RISDON C.J.E. *Shrinkage and Density of Australian and Other South-west Pacific Woods*. Division of Forest Products Technological Paper No. 13, CSIRO, 1961.
- (b) BUDGEN, B. *Shrinkage and Density of some Australian and South-east Asian Timbers*. Division of Building Research Technological Paper (Second Series) No. 38, CSIRO, 1981.

1.4.4.5 Durability

A1 | The structure and its structural elements (including timber, metal, adhesives and other structural material) shall be designed to satisfy the strength, stability and serviceability requirements for the design life of the structure. Any assumed maintenance program shall be specified. Due consideration shall be given to environmental conditions, such as the thermal, physical, chemical, mechanical and biological agents that may act on the structure to reduce its performance characteristics.

NOTES:

- 1 Generally, timber under cover and in well-ventilated conditions and not in contact with the ground water or free water is not subject to fungal attack. However, such timber may be subject to termite attack and to attack by other insects in parts of Australia. If conditions favourable for biological attack exist, then steps should be taken to eliminate the hazards. This is particularly important in structures where there is no load-sharing capacity, or there is a high consequence of failure.
- 2 Information on the durability design of timber structures and components thereof can be obtained from the following:
 - (a) All hazards:

Design for Durability, Datafile P4, National Association of Forest Industries Timber Manual.

STRINGER G.R. *The Development of Reliability Based Durability Design Methods for Timber Structures*, Gottstein Report 1994.
 - (b) Fire—AS 1720.4.
 - (c) Biological hazards:

Subterranean termites—The AS 3660 series.

Marine organisms—CSIRO, Marine Borers and Timber Piling Options.

Insects and fungi—AS 1604.1.
 - (d) Timber for houses:

Timber framing—The AS 1684 series.
 - (e) Metal connectors, corrosion—AS 4100.
 - (f) Timber adhesives—AS 2754.1(Int).
 - (g) Timber service life—*Timber Service Life Design Guide*, Forest and Wood Products Australia, 2007.

1.5 DESIGN AND SUPERVISION

1.5.1 Design

The design of timber structures to which this Standard applies, including the specification of materials and any protective treatment, shall be carried out in accordance with the requirements of this Standard.

1.5.2 Design information

The following information, appropriate to the design, shall be shown on the drawings:

- (a) Reference number and date of the Standards used for the design.
- (b) Dead, live, wind, snow and earthquake loads used in design.
- (c) Strength group, joint group, stress grade and grading Standard used for design.
- (d) Species or group of species of timber or plywood to be used.
- (e) In-service moisture and temperature regime for which the structure has been designed.
- (f) Protective treatment, if applicable.
- (g) Fire-resistance rating, if applicable.
- (h) Type of glue, if applicable.
- (i) Standard of inspection to be employed during construction.
- (j) Any other information that is critical to design.

1.5.3 Design details

The drawings and specification shall include the following, where appropriate:

- (a) Size, characteristic value and moisture content of each member.
- (b) Dimensioned details of all joints, connections and splices and their locations.
- (c) Sizes and types of fasteners.
- (d) Camber in any member.
- (e) Any constraint on construction assumed in design.
- (f) Surface finish of any member.
- (g) Any special maintenance requirements.
- (h) Any other requirements.

1.5.4 Supervision

The fabrication and erection of the timber structures or the parts of structures to which this Standard applies shall be supervised to ensure that all of the requirements of the design are satisfied in the completed structure.

1.6 WORKMANSHIP AND MAINTENANCE

1.6.1 General

The requirements of the designer, as specified in the design documents, shall be satisfied in the completed structure during its service life.

1.6.2 Moisture content

When structures or elements are to be fabricated with seasoned timber in situations where dimensional stability is critical, the designer of the structure shall ascertain the average equilibrium moisture content for the environment in which the structures or elements are to be erected, and shall specify that each piece of timber to be used shall have an average moisture content at the time of fabrication that is within 3% of the equilibrium value.

NOTE: Information on equilibrium moisture content values in timbers located in Australia can be obtained from the following references:

- (a) FINIGHAN, R. *Moisture Content Predictions for Eight Seasoned Timbers under Sheltered Outdoor Conditions in Australia and New Guinea*. Division of Forest Products Technological Paper No. 44, CSIRO, 1966.
- (b) BRAGG, C. *An Equilibrium Moisture Content Survey of Timber in Queensland*. Queensland Department of Forestry Technical Paper No. 40, QFD, 1986.
- (c) BRENNAN G.K. and PITCHER J.A. *Equilibrium Moisture Content Variation of Timbers commonly used in Western Australia*. CALM Science Volume 2 No. 1 p.25-50, 1995.

1.6.3 Corrosion

The designer of the structure shall take due account of any possible corrosive effects on metal connectors or fasteners.

NOTE: Information on the protection of steel can be obtained from AS/NZS 2312.

1.6.4 Shop drawings

Where specified, shop drawings shall be prepared for structural members.

1.6.5 Fabrication and erection

The structure shall be fabricated and erected in accordance with the designer's instructions.

1.6.6 Maintenance

The structure shall be maintained during its service life in a condition that satisfies the designer's requirements as specified in the design documents.

1.7 DEFINITIONS

For the purpose of this Standard, the definitions given in AS/NZS 4491 and those below apply. Where the definitions in AS/NZS 4491 differ from those listed herein, those in this Standard shall apply.

1.7.1 Administrative definitions

1.7.1.1 Building authority or other regulatory authority

Body having statutory powers to control the design and erection of buildings or structures, including scaffolding, in the area in which the building or structure concerned is to be erected.

1.7.1.2 Professional engineer

A person who is—

- (a) if legislation is applicable, a registered *professional engineer* in the relevant discipline, who has appropriate experience and competence in the relevant field; or

- (b) if legislation is not applicable—
 - (i) a Corporate Member of Engineers Australia or the Institution of Professional Engineers New Zealand; or
 - (ii) eligible to become a Corporate Member of Engineers Australia or the Institution of Professional Engineers New Zealand and has appropriate experience and competence in the relevant field.

1.7.2 Technical definitions

1.7.2.1 A17-grade timber

A stress grade of timber for which the specific suite of characteristic values given in Table H3.1, Appendix H, are applicable.

NOTE: A17-grades are assigned to seasoned hardwood timber in accordance with the grading Standard AS 2082.

1.7.2.2 Characteristic capacity

The product of characteristic value and geometric section property appropriate to the action effect (see Clause 2.1.2).

1.7.2.3 Capacity factor

A factor applied to the characteristic capacity to obtain the design capacity (see Clause 2.1.2).

1.7.2.4 Design characteristic value/characteristic value for design

A specific design property suitable for use in the calculation of design capacity of a structural element.

NOTE: This definition may differ from the meaning given or applied in other contexts

1.7.2.5 Collapse-susceptible timber

Timber, for which the shrinkage values before and after reconditioning differ by more than 2%.

NOTE: Information on shrinkage values can be obtained from the following references:

- (a) KINGSTON, R.S.T. and RISDON C.J.E. *Shrinkage and Density of Australian and Other South-west Pacific Woods*. Division of Forest Products Technological Paper No. 13, CSIRO, 1961.
- (b) BUDGEN, B. *Shrinkage and Density of some Australian and South-east Asian Timbers*. Division of Building Research Technological Paper (Second Series) No. 38, CSIRO, 1981.

1.7.2.6 Corewood

Timber adjacent to or including the pith, that is, of density less than 80% that of the density of mature trees.

NOTE: For plantation grown softwoods, corewood may be avoided by excluding all timber within a radius of 50 mm from the centre of the pith that has a growth ring width greater than 6 mm (see also Clause 4.1.4).

1.7.2.7 Design action effect or design load effect

The action or load effect computed from the design actions or design loads.

1.7.2.8 Design action or design load

The combination of the nominal actions or loads and the load factors, as specified in AS/NZS 1170.0.

1.7.2.9 Design capacity

The product of the capacity factor, modification factors and characteristic capacity of a structural element (see Clause 2.1.2).

1.7.2.10 *Design life*

Period over which a structure or structural element is required to perform its function without repair.

1.7.2.11 *Design resistance effect*

The resistance effect computed from the loads and design capacities contributing towards the stability limit state resistance.

1.7.2.12 *Duration of loading*

Period during which a member, a structural element or a complete structure is subject to a specified load level.

NOTES:

- 1 For the purposes of interpretation in the use of load-duration factors in this Standard, see Clause 2.4.1.
- 2 The strength and stiffness properties of timber under load are time dependent.

1.7.2.13 *F-grade timber*

A stress grade of timber for which the specific suite of characteristic values given in Table H2.1, Appendix H are applicable.

NOTE: F-grades may be assigned to graded timber in accordance with the appropriate grading Standard, i.e., AS 2082, AS 2858, AS/NZS 1748 or AS 3519.

1.7.2.14 *Hardwood*

A wood from trees classified botanically as *Angiosperm*.

NOTES:

- 1 Although the term ‘hardwood’ is popularly interpreted to indicate the relative hardness of the wood, this interpretation is misleading as the wood of many hardwoods is relatively soft (e.g., balsa wood).
- 2 The structural difference between hardwoods and softwoods is that hardwoods have vessels or pores and softwoods do not; that is, the wood of softwoods does not include pores.

1.7.2.15 *Joint group*

The classification assigned to a timber species or species group for the purpose of calculating joint capacity.

NOTES:

- 1 Unseasoned timber species or species groups are classified into six joint groups (i.e., J1 to J6). Seasoned timber species or species groups are classified into six joint groups (i.e., JD1 to JD6).
- 2 The joint group classifications for a range of timber species or species groups are given in Tables H2.3, H2.4, and H3.1, Appendix H for hardwoods and softwoods.
- 3 Joint group is defined for the purpose of this Standard only; the classifications are not necessarily applicable for proprietary fasteners (e.g., multi-toothed nailplates).

1.7.2.16 *Limit state*

Any limiting condition beyond which the structure ceases to fulfil its intended function.

1.7.2.17 *MGP grade timber*

A stress grade of timber for which the specific suite of characteristic values given in Table H3.1, Appendix H, are applicable.

NOTE: MGP grades are assigned to seasoned softwood timber graded in accordance with AS/NZS 1748.

1.7.2.18 *Primary structural element*

Members and joints whose failure could result in collapse of a significant portion of a structure.

1.7.2.19 Proof testing

Application of test loads to a structure or element to ascertain the structural characteristics of only that one unit under test.

1.7.2.20 Prototype testing

Application of test loads to a structure or element to ascertain the structural characteristics of structures or elements which are nominally identical to the unit or units tested.

1.7.2.21 Seasoned timber

Timber in which the average moisture content is nominally between 10 and 15%.

NOTE: Seasoned timber is sometimes referred to as ‘dry’, ‘air-dried’ or ‘kiln-dried’ timber.

1.7.2.22 Secondary structural elements

Members and joints whose failure would result in a localized collapse.

1.7.2.23 Serviceability limit state

A limit state of acceptable in-service condition.

1.7.2.24 Softwood

Wood from trees classified botanically as *Gymnosperm*.

NOTES:

- 1 Although the term ‘softwood’ is popularly interpreted to indicate the relative softness of the wood, this interpretation is misleading as the wood of many softwoods can be relatively hard (e.g., cypress pine).
- 2 Commercial species of this group are nearly always conifers.

1.7.2.25 Stability limit state

A limit state corresponding to the loss of static equilibrium of a structure considered as a rigid body.

1.7.2.26 Strength group

The classification assigned to a timber species or species group for the purposes of determining characteristic values for bearing, shear at joint details and tension perpendicular to grain.

NOTES:

- 1 Unseasoned timber species or species groups are classified into seven strength groups (i.e., S1 to S7). Seasoned timber species or species groups are classified into eight strength groups (i.e., SD1 to SD8).
- 2 The strength group classifications for a range of timber species or species groups are given in Tables H2.3, H2.4, and H3.1, Appendix H, for hardwoods and softwoods.
- 3 Procedures for assigning species to strength group classifications are given in AS 2878.

1.7.2.27 Strength limit state

A limit state of collapse or loss of structural integrity.

1.7.2.28 Stress grade

A classification assigned to structural timber or wood products that indicates a suite of characteristic values of strength and stiffness properties suitable for structural design.

NOTE: Typical examples of stress grades are—

- (a) F-grades for sawn timber as given in Table H2.1 of Appendix H;
- (b) MGP grades for sawn timber as given in Table H3.1 of Appendix H;
- (c) A17 grades for sawn timber as given in Table H3.1 of Appendix H;
- (d) F-grades for plywood as given in Table 5.1;
- (e) GL grades for glued laminated timber as given in Table 7.1; and
- (f) proprietary stress grades detailed in a manufacturer’s product specification.

1.7.2.29 *Structural element*

A member and/or joint that fulfils a structural function.

1.7.2.30 *Structural timber*

Timber with defined structural properties that meet the requirements of this Standard.

1.7.2.31 *Unseasoned timber*

Timber in which the average moisture content exceeds 25%.

NOTE: Unseasoned timber is sometimes referred to as 'green' timber.

1.8 NOTATION

Except where specifically defined in a particular Clause, the quantity symbols and factors shall be as listed in Appendix F.

1.9 UNITS

Unless otherwise stated, the units of measurement used in this Standard shall be in accordance with the International System of Units (SI).

NOTE: In general, newtons (N), millimetres (mm) and megapascals (MPa) are appropriate units to be used.

SECTION 2 DESIGN PROPERTIES OF STRUCTURAL TIMBER ELEMENTS

2.1 GENERAL

2.1.1 General procedure

Design capacities for structural timber shall be obtained through modifying characteristic capacities by factors appropriate to the service conditions and material property type. This general procedure applies to all types of structural timber, including sawn timber, laminated timber, natural round timber, plywood and laminated veneer lumber except where otherwise specified.

NOTE: Appendix G gives references for additional information on species design properties and examples of load duration factors for typical combinations of actions.

2.1.2 Member design capacity

The design capacity (R_d) of a structural member is the product of the characteristic value of the material, the appropriate geometric property, factors to allow for variation in strength with the environment and configuration of the element in use, and a capacity factor, and is expressed as follows:

$$R_d = \phi k_{\text{mod}} f'_o X \quad \dots 2.1$$

where

- ϕ = capacity factors (see Clause 2.3)
- k_{mod} = product of modification factors as defined in Clause 2.4 and elsewhere in this Standard ($k_1 \times k_4 \dots \times k_n$)
- $f'_o X$ = characteristic capacity appropriate to the action effect
- f'_o = characteristic value of material design property (e.g., bending, tension, etc.), in megapascals
- X = geometric sectional property of member appropriate to the method of load application to produce a particular failure mode

NOTE: As an example the factor k_{mod} for design moment capacity in bending of a solid timber member is typically given by $k_{\text{mod}} = k_1 k_4 k_6 k_9 k_{12}$. The appropriate geometric property is section modulus (Z) and the appropriate characteristic value is f'_b , giving the following design capacity:

$$M_d = \phi k_1 k_4 k_6 k_9 k_{12} f'_b Z$$

2.1.3 Design rigidity of members

The design rigidity is the product of the relevant section property and the average modulus of elasticity (or modulus of rigidity) applicable for the stress grade.

2.1.4 Design capacity of joints

The design capacity of joints (R_d) required to resist direct loads, as a generalization, is the product of the characteristic capacity of the fastener, factors to allow for the environment of use and configuration of the joint and a capacity factor, expressed as follows:

$$R_d = \phi k_{\text{mod}} n Q \quad \dots 2.2$$

where

ϕ = capacity factor (see Clause 2.3)

k_{mod} = product of modification factors as defined in Clause 2.4 and Section 4
($k_1 \times k_2 \times \dots \times k_n$)

Q = characteristic capacity for the fastener type, size and load and fastener orientation, as appropriate, in newtons

n = number of fasteners

NOTE: Expressions for the design capacity of joints (R_d) required to resist in-plane moments are given in Section 4.

2.2 DESIGN PROPERTIES

2.2.1 Characteristic values for calculating the design capacity of members

The characteristic values for strength and elastic moduli for the design of structural elements using standardized stress grades of structural sawn timber, structural plywood, round timber, glue-laminated timber and structural laminated veneer lumber are obtained as follows:

- (a) For F-grades, MGP grades and A17 grades of solid sawn timber refer to Appendix H.
- (b) For F-grades for structural plywood, refer to Section 5.
- (c) For round timbers, refer to Section 6 and Appendix H.
- (d) For GL-grades for glue-laminated timber, refer to Section 7.
- (e) For structural laminated veneer lumber, refer to Section 8.

2.2.2 Characteristic values for calculating the design capacity of joints

The characteristic capacities used to calculate the design capacity of joints using nails, screws, bolts, coach screws, split-ring and shear-plate connectors shall be as given in Section 4 for species joint groups. Joint group classifications for species and moisture condition shall be as given in Appendix H.

2.3 CAPACITY FACTOR

Values of the capacity factor (ϕ) for calculating the design capacity, R_d , of structural members and structural joints are listed in Table 2.1 and Table 2.2, respectively, for material and fastener types and structural application.

TABLE 2.1
VALUES OF CAPACITY FACTOR (ϕ) FOR CALCULATING THE DESIGN CAPACITY (R_d) OF STRUCTURAL MEMBERS

	Application of structural member		
	Category 1	Category 2	Category 3
	Structural members for houses for which failure would be unlikely to affect an area* greater than 25 m ² ; OR secondary members in structures other than houses	Primary structural members in structures other than houses; OR elements in houses for which failure would be likely to affect an area* greater than 25 m ²	Primary structural members in structures intended to fulfill an essential service or post disaster function
Structural timber material	Values of capacity factor (ϕ)		
Sawn timber—AS 2082, AS 2858, AS/NZS 1748, AS 3519: —Stress grades: MGP 15, A17, F17 and higher F-grades —All other timber† and stress grades	0.95 0.90	0.85 0.70	0.75 0.60
Round timber— AS 3818.3 or AS 3818.11, as appropriate	0.90	0.70	0.60
Glue-laminated timber—AS/NZS 1328.1	0.95	0.85	0.75
Structural plywood—AS/NZS 2269.0	0.95	0.85	0.75
Structural laminated veneer lumber—AS/NZS 4357.0	0.95	0.90	0.80

NOTE: Refer to definitions: secondary structural element in Clause 1.7.2.22; primary structural element in Clause 1.7.2.18.

* In this context, area should be taken as the plan area.

† Indicates design capacities determined using the characteristic values from Table H2.2, Appendix H.

TABLE 2.2
VALUES OF CAPACITY FACTOR (ϕ) FOR CALCULATING THE DESIGN CAPACITY (N_d) OF STRUCTURAL JOINTS

Type of fastener and applicable Australian product standards	Application of structural member		
	Category 1	Category 2	Category 3
	Structural joints for houses for which failure would be unlikely to affect an area ⁽¹⁾ greater than 25 m ² ; OR Joints for secondary elements ⁽²⁾ in structures other than houses	Primary structural joints ⁽²⁾ in structures other than houses; OR joints for house construction for which failure of the joint would be likely to affect an area ⁽¹⁾ greater than 25 m ²	Primary structural joints ⁽¹⁾ in structures intended to fulfill an essential services or post disaster function
	Capacity factor (ϕ)		
Nails conforming to AS 2334	0.85	0.80	0.75
Screws conforming to the AS 3566 series	0.85	0.80	0.75
Multi-toothed nail plates conforming to manufacturer's specifications	0.85	0.80	0.75
Bolts conforming to AS 1111.1 —M16 and smaller —larger than M16	0.85 0.75	0.80 0.65	0.75 0.60
Coach screws conforming to AS/NZS 1393 —M16 and smaller —larger than M16	0.85 0.75	0.80 0.65	0.75 0.60
Split-ring fasteners conforming to AS 1442	0.75	0.65	0.60
Shear-plate fasteners conforming to AS 1442	0.75	0.65	0.60

NOTES:

- 1 In this context, area should be taken as the plan area. In most instances, a category 2 joint will be required for support of a category 2 member.
- 2 Refer to definitions: secondary structural elements in Clause 1.7.2.22; primary structural elements (joints) in Clause 1.7.2.18.

2.4 MODIFICATION FACTORS

2.4.1 Duration of load

2.4.1.1 *Effect on strength*

The effect of duration of load on strength is given by the modification factor k_1 in Table 2.3.

In checking the design capacity of a structural element, all combinations of actions shall be considered.

For any given combination of loads of differing duration, the factor k_1 to be used is that appropriate to the action that is of the shortest duration. In Table 2.3, the effective duration of a peak action refers to the cumulative duration for which the peak action occurs.

For the purposes of interpretation in the selection of load-duration factors for calculation of design capacity, the following shall apply:

- (a) Permanent actions and the long-term components of imposed actions shall be considered of ‘50 or more years duration’.
- (b) Imposed actions that act on floors (such as those due to vehicles or people), and are applied at frequent but irregular intervals such that the structure is unloaded or loaded well below the nominal imposed action for most of each day, shall be considered to be of ‘five months duration’.
- (c) Imposed actions, such as those arising during erection and maintenance, and imposed actions that are infrequent (e.g., crowd loads), applied for periods of a few days and at infrequent intervals, shall be considered to be of ‘five days duration’.
- (d) Impact actions, such as those caused by falling weights or snatch lifts, shall be considered to be of ‘five seconds duration’.
- (e) Snow action shall be considered to be of the following durations:
 - (i) For alpine areas 5 months.
 - (ii) For sub-alpine areas 5 days.
- (f) Earthquake actions shall be considered to be of ‘five seconds duration’.
- (g) Strength limit state gust wind actions referred to in AS/NZS 1170.2 shall be considered to be of ‘five seconds duration’.
- (h) For the fire limit state, the duration of actions shall be considered to be of ‘five days duration’.

NOTE: The critical strength limit state load combination may not be the one with the highest value because the resistance of timber to load is a function of duration of load. In some cases, load combinations involving longer term loads of lesser load effect may be more critical than combinations involving shorter term loads.

TABLE 2.3
DURATION OF LOAD FACTOR FOR STRENGTH

Effective duration of peak action	Modification factor (k_1)*	
	For the strength of timber	For the strength of joints using laterally loaded fasteners†
5 seconds	1.00	1.14
5 minutes	1.00	1.00
5 hours	0.97	0.86
5 days	0.94	0.77
5 months	0.80	0.69
50+ years	0.57	0.57

* Typical values of k_1 for various load combinations are given in Table G1, Appendix G.

† For the strength of joints with fasteners loaded in withdrawal and for the strength of steel in joints, $k_1 = 1.00$.

2.4.1.2 Effect on deformation

For members in bending and compression and shear deformation or tensile deformation, the calculated short-term deformation shall be multiplied by the appropriate modification factor for creep (j_2 or j_3), as given in Table 2.4 and illustrated graphically in Figures 2.1 and 2.2.

Values intermediate between those given in Table 2.4 shall be obtained by interpolation involving the logarithm of time, and a linear function of initial moisture content as shown in Figures 2.1 and 2.2.

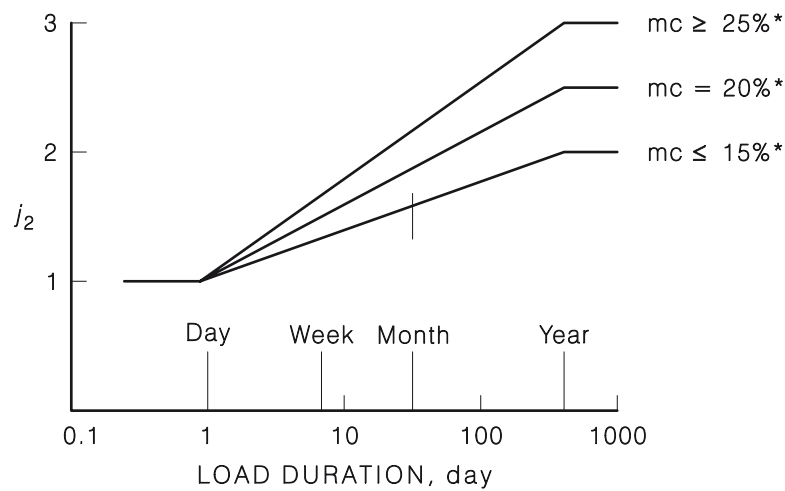
When several types of action contribute to deformation, the maximum deformation shall be taken to be equal to the sum of the deformations computed for each type of load acting alone.

Where there is a recovery period of more than 10 times the period of the applied action between applications, the creep component of deformation for that action type shall be assumed to be totally recovered.

The modification factors j_2 and j_3 , given in Table 2.4, are not applicable to collapse-susceptible hardwoods (see Clause 1.7.2) that are unseasoned at the time of loading (see Note 3 below).

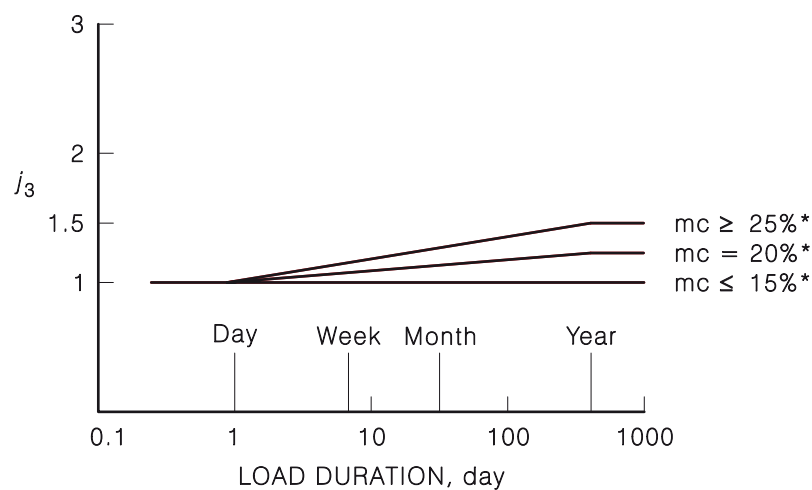
NOTES:

- 1 In general, peak values of serviceability-imposed actions are not of a permanent nature; accordingly, if a designer wishes to compute the long-term deformations of a structure to satisfy a specified serviceability limit state, the designer first estimates the portion of the serviceability load that is permanently or semi-permanently applied and then uses an appropriate creep factor to compute the deformation for that portion.
- 2 The duration of actions specified for calculation of design capacity are not intended for estimation of deformation.
- 3 For collapse susceptible hardwoods in the unseasoned condition, the creep factors j_2 and j_3 may be considerably greater than values given in Table 2.4.



* Initial moisture content

FIGURE 2.1 DURATION FACTOR (j_2) FOR BENDING AND COMPRESSION DEFORMATIONS



* Initial moisture content

FIGURE 2.2 DURATION FACTOR (j_3) FOR TENSION DEFORMATIONS

TABLE 2.4
DURATION OF LOAD FACTOR FOR CREEP DEFORMATION

Initial moisture content*	For bending, compression and shear members (j_2)		For tension members (j_3)	
	Duration of action		Duration of action	
	≤1 day	≥1 year	≤1 day	≥1 year
≤15	1	2	1	1
≥25	1	3	1	1.5

* Moisture content at the time of load application.

2.4.2 Moisture condition

2.4.2.1 General

Depending on the initial moisture content of the timber and the moisture content at time of loading and throughout its life, the characteristic capacity of timber shall be modified by a factor denoted by k_4 .

NOTE: For appropriate values of k_4 for glulam, refer to Clause 7.4.2, and for laminated veneer lumber (LVL) to Clause 8.4.3.

2.4.2.2 Unseasoned timber

For unseasoned timber, generally k_4 equals 1.0. Where unseasoned timber is used under normal conditions of temperature and humidity and will not be subject to its full design load until it has partially seasoned (i.e., to below 25% moisture content), it is permissible to increase the characteristic capacity for unseasoned timber by multiplying by the factor k_4 given in Table 2.5.

TABLE 2.5
PARTIAL SEASONING FACTOR (k_4)

Least dimension of member	38 mm or less	50 mm	75 mm	100 mm or more
Value of k_4	1.15	1.10	1.05	1.00

2.4.2.3 Seasoned timber

For seasoned timber, generally k_4 equals 1.0. Where seasoned timber is subjected to conditions in which its average moisture content for a 12 month period is expected to exceed 15%, the characteristic capacity shall be decreased.

The value of k_4 shall be determined as the greater of—

(a) $k_4 = 1 - 0.3 \frac{EMC - 15}{10}$; and

(b) $k_4 = 0.7$;

where EMC is the highest value of the annual average moisture content (percent) that the timber will attain in service.

2.4.3 Temperature

For covered timber structures under ambient conditions, no modification for strength need be made for the effect of temperature (i.e., k_6 equals 1.0) except that where seasoned timber is used in structures erected in coastal regions of Queensland north of latitude 25°S, and all other regions of Australia north of latitude 16°S, the strength shall be modified by a factor k_6 of 0.9.

NOTE: Information on the effects of high temperatures can be obtained from MEYER, R.W. and KELLOG, R.M. *Structural Use of Wood in Adverse Environments*, Van Nostrand, 1982.

2.4.4 Length and position of bearing

Where rectangular bearing areas are located 75 mm or more from the end of a piece of timber, it is permissible to increase the characteristic capacity in bearing perpendicular to the grain (refer to Clause 3.2.6) by the appropriate value of factor k_7 in Table 2.6. The length of bearing shall be measured parallel to the grain of the loaded member. For all other conditions k_7 equals 1.0.

For circular bearing areas, the effective bearing length shall be taken as being equal to the diameter of the bearing area.

TABLE 2.6
LENGTH OF BEARING FACTOR

Length of bearing of member	12	25	50	75	125	150 or more
Value of k_7	1.75	1.40	1.20	1.15	1.10	1.00

2.4.5 Strength sharing between parallel members

2.4.5.1 General

When a sawn timber structural member is one of a number of parallel acting elements that interact to assist each other to form a strength-sharing structural system, it is permissible to increase the characteristic capacities in bending for sawn structural timber by the strength-sharing factor (k_9) determined in accordance with Clause 2.4.5.3. Values of the strength-sharing factor (k_9) specified in this Clause shall not apply to plywood, glued laminated timber and LVL members (see Sections 5, 7 and 8).

NOTE: In addition to strength-sharing structural systems, grid systems provide a method for laterally distributing concentrated loads (see Appendix E).

2.4.5.2 Strength-sharing structural systems

Parallel acting systems are classified as follows:

- (a) Combined parallel systems.
- (b) Discrete parallel systems.

A combined parallel system is comprised of two or more elements that are effectively fastened together.

In determining the factor k_9 for a combined parallel system, the effective number of elements shall be taken as the number of elements (n_{com}) that are effectively fastened together to form a single group.

NOTES:

- 1 An example of a combined parallel system is illustrated in Figure 2.3(a).
- 2 Effectively fastened together means that all of the elements are constrained to the same deformation under load.
- 3 One method of effectively fastening elements together is by rigidly connecting all of the elements together at a large number of points along their length.

A discrete parallel system has three or more members that are discretely spaced parallel to each other. These discretely spaced members support either an overlying set of members, usually laid at right angles to the supporting members, or a structural sheathing material.

In determining the factor k_9 for a discrete parallel system, the effective number of elements shall be taken as the product of—

$$n_{\text{com}} \times n_{\text{mem}}$$

where

n_{com} = number of elements that are effectively fastened together to form a single group

n_{mem} = number of members that are discretely spaced parallel to each other

NOTES:

- 1 Examples of discrete parallel systems are illustrated in Figures 2.3(b) and 2.3(c).
- 2 For a parallel system, in the event of the failure of a single supporting member, then the overlying members or sheathing material should be capable of transferring loads to adjacent supporting members.

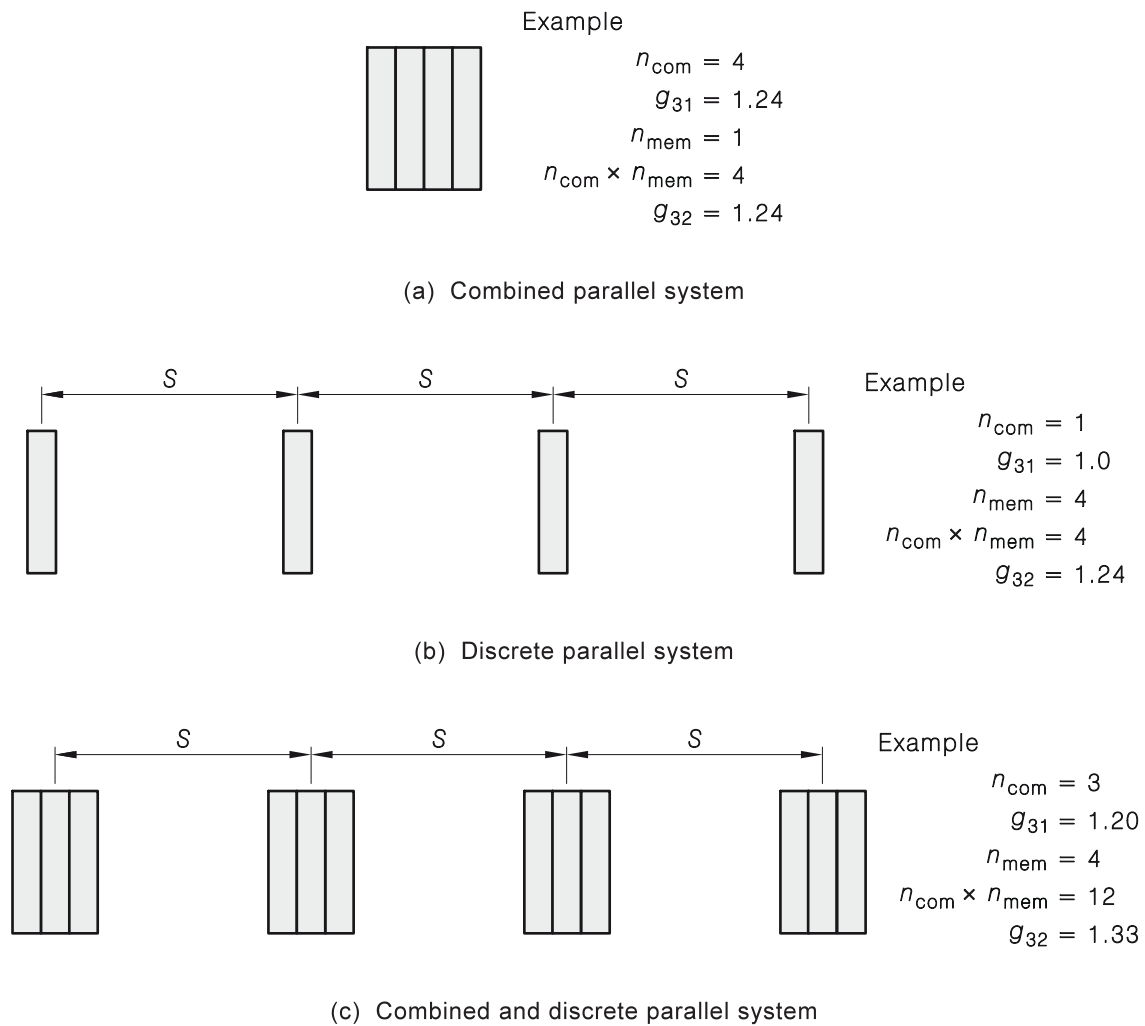


FIGURE 2.3 PARALLEL SYSTEMS

2.4.5.3 *Modification factor for strength sharing*

The strength-sharing factor k_9 is given by the following equation:

$$k_9 = g_{31} + (g_{32} - g_{31}) \left[1 - \frac{2s}{L} \right], \text{ but not less than } 1.0 \quad \dots 2.4.5.3$$

where

g_{31} = geometric factor appropriate to the number of members (n_{com}) in a combined parallel system given in Table 2.7

g_{32} = geometric factor appropriate to the number of members ($n_{\text{com}} \times n_{\text{mem}}$) in a discrete system given in Table 2.7

s = centre-to-centre spacing of the discrete parallel members

L = effective span of the parallel members

The strength-sharing factor k_9 is illustrated graphically in Figure 2.4.

TABLE 2.7
GEOMETRIC FACTORS FOR PARALLEL SYSTEMS

Number of members in combined parallel (n_{com})	g_{31}	Total number of members in parallel system ($n_{\text{com}} \times n_{\text{mem}}$)	g_{32}
1	1.00	1	1.00
2	1.14	2	1.14
3	1.20	3	1.20
4	1.24	4	1.24
5	1.26	5	1.26
6	1.28	6	1.28
7	1.30	7	1.30
8	1.31	8	1.31
9	1.32	9	1.32
10 or more	1.33	10 or more	1.33

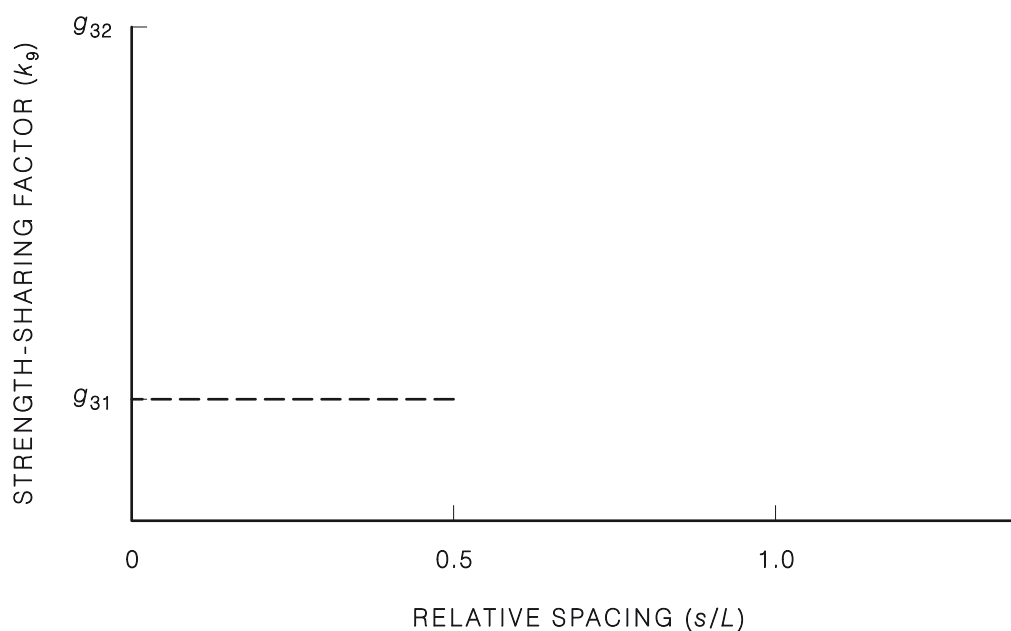


FIGURE 2.4 STRENGTH-SHARING FACTOR (k_g)

2.4.6 Stability factor

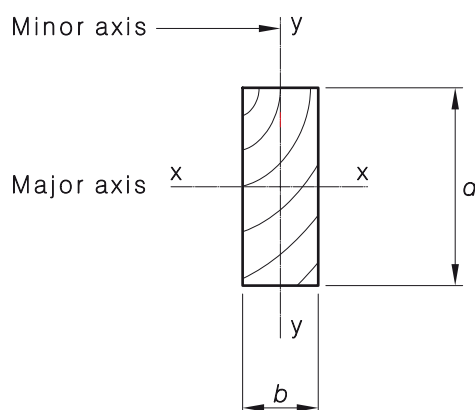
In the design of slender bending or axial compression members, a factor k_{12} shall be used to allow for the effects of slenderness on strength. The stability factor is defined in Clause 3.2.4 for bending members and Clause 3.3.3 for compression members.

SECTION 3 DESIGN CAPACITY OF BASIC STRUCTURAL MEMBERS

3.1 GENERAL

This Section shall be applied in conjunction with Section 2. This Section applies to the design of basic structural members such as beams, columns and tension members. In particular, many of the design parameters given herein refer to members of rectangular cross-section, for which the notation used is shown in Figure 3.1. The corresponding parameters for members of less usual shape shall be as given in Appendix E. Special design requirements related to the use of plywood, pole timbers, glued-laminated construction and laminated veneer lumber are given in Sections 5, 6, 7 and 8 respectively. Methods using a higher order approach to the design of members and for particular cases are given in Appendix E.

NOTE: In beam design, deflection considerations may govern member sizes (see Clauses 1.4.2.4 and 2.4.1.2).



NOTE: For design dimensions, see Clause 1.4.3.

FIGURE 3.1 NOTATION FOR A RECTANGULAR CROSS-SECTION

3.2 BEAM DESIGN

3.2.1 Bending strength

3.2.1.1 Design capacity

The design capacity in bending (M_d) of unnotched beams, for the strength limit state, shall satisfy the following:

$$M_d \geq M^* \quad \dots 3.2(1)$$

where

$$M_d = \phi k_1 k_4 k_6 k_9 k_{12} f'_b Z \quad \dots 3.2(2)$$

and

M^* = design action effect in bending (see Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

k_1 to k_9 = the modification factors given in Section 2

k_{12} = stability factor (see Clause 3.2.4)

- f'_b = characteristic value in bending for the section size
- Z = section modulus of beam about the axis of bending (for rectangular beams Z_x equals $bd^2/6$ and Z_y equals $db^2/6$, where b equals the breadth and d equals the depth of the beam).

3.2.1.2 Bending about both axes

For beams that can bend about both the major and minor axes simultaneously, for strength limit states, the design action effects in bending shall satisfy the following equation:

$$\frac{M_x^*}{M_{d,x}} + \frac{M_y^*}{M_{d,y}} \leq 1 \quad \dots 3.2(3)$$

where

M_x^* = design action effect in bending about the major principal x-axis (see Clause 1.4.2.2)

$M_{d,x}$ = design capacity in bending about the major principal x-axis determined according to Clause 3.2.1

M_y^* = design action effect in bending about the minor principal y-axis (see Clause 1.4.2.2)

$M_{d,y}$ = design capacity in bending about the minor principal y-axis determined according to Clause 3.2.1

For less conservative criteria than given by Equation 3.2(3), see Equations E5(1) and E5(2), Appendix E.

3.2.2 Effective span

The effective span of flexural members shall be taken as the distance between the centres of areas of bearing or of connections.

For members that extend over bearings longer than is necessary, it is appropriate to measure the span as the distance between centres of imaginary bearings which are chosen in such a way that their lengths are adequate to comply with the requirements of this Standard.

3.2.3 Slenderness coefficient for lateral buckling under bending

3.2.3.1 General

For the general case, and for several useful specific cases, equations for evaluating the slenderness coefficient are given in Appendix E. For special cases of solid beams of rectangular cross-section, the simple approximations given in Clause 3.2.3.2 are acceptable. The notation for beam restraints is shown in Figures 3.2 to 3.6.

3.2.3.2 Beams of rectangular cross-section

Approximations of slenderness coefficients for typical load and restraint conditions are given as follows:

- (a) *Beams that bend about their major axis having discrete lateral restraint systems* For a beam that is loaded along its compression edge and has discrete lateral restraints at points L_{ay} apart, along the compression edge of the beam as indicated in Figure 3.2, the slenderness coefficient, denoted by S_1 , is—

$$S_1 = 1.25 \frac{d}{b} \left(\frac{L_{ay}}{d} \right)^{0.5} \quad \dots 3.2(4)$$

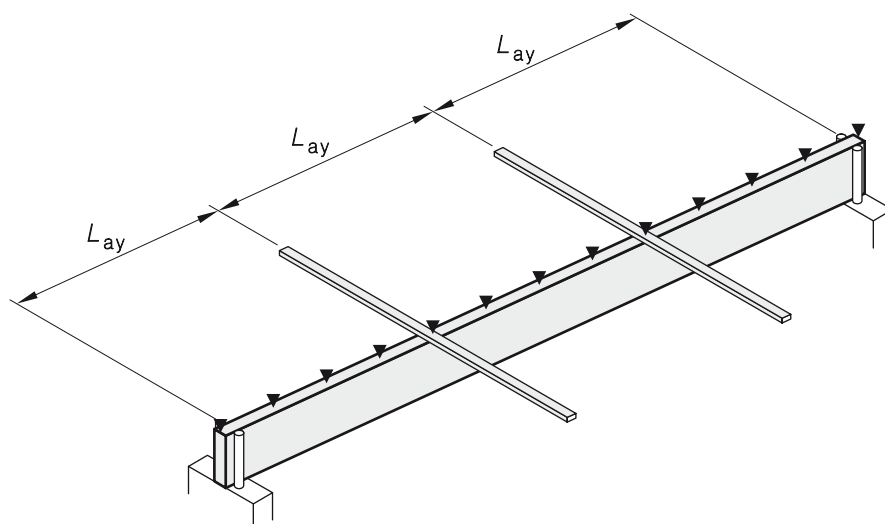


FIGURE 3.2 DISCRETE RESTRAINTS TO THE COMPRESSION EDGE

For a beam that is loaded along its tension edge and has discrete lateral restraints at points L_{ay} apart, along the tension edge of the beam as indicated in Figure 3.3, then the slenderness coefficient, denoted by S_1 , is—

$$S_1 = \left(\frac{d}{b} \right)^{1.35} \left(\frac{L_{ay}}{d} \right)^{0.25} \quad \dots 3.2(5)$$

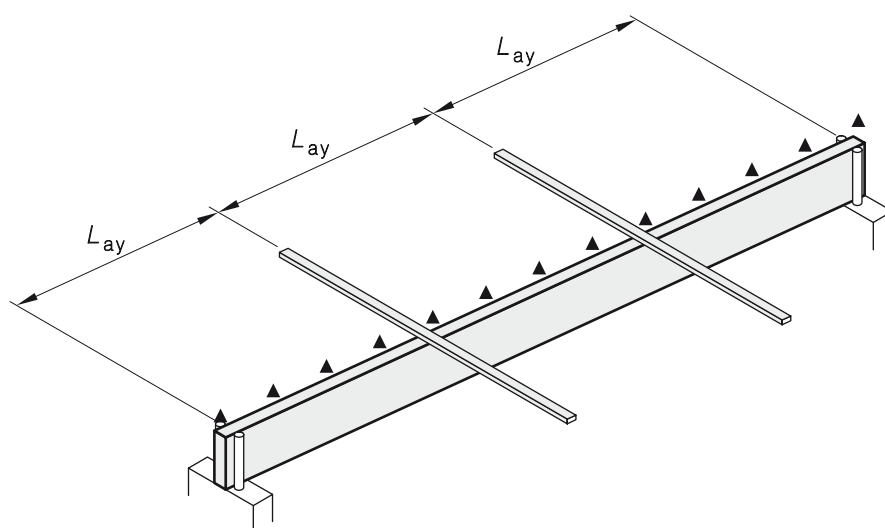


FIGURE 3.3 DISCRETE RESTRAINTS TO THE TENSION EDGE

- (b) *Beams that bend about their major axis having continuous lateral restraint systems* A continuous lateral restraint system (see Figures 3.4 and 3.5) shall be assumed to exist when—

$$\frac{L_{ay}}{d} \leq 64 \left(\frac{b}{\rho_b d} \right)^2 \quad \dots 3.2(6)$$

For a beam that is loaded along its compression edge and has a continuous lateral restraint system along the compression edge (see Figure 3.4), the slenderness coefficient, denoted by S_1 , shall be taken to be equal to zero.

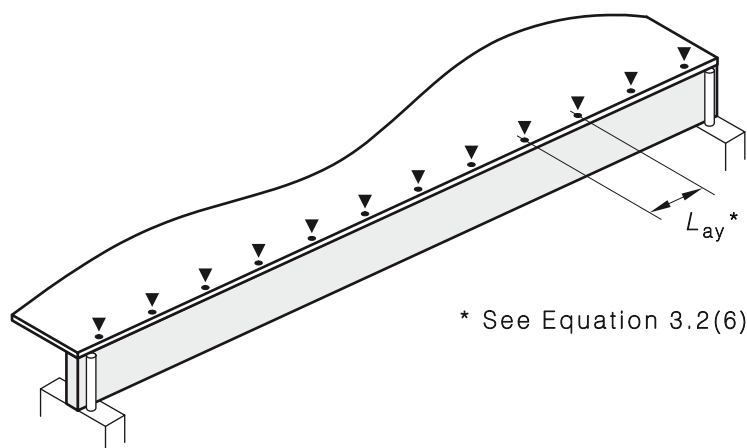


FIGURE 3.4 CONTINUOUS RESTRAINT ALONG THE COMPRESSION EDGE

For a beam that is loaded along its tension edge and has a continuous lateral restraint system along the tension edge (see Figure 3.5), the slenderness coefficient, denoted by S_1 , is—

$$S_1 = 2.25 \frac{d}{b} \quad \dots 3.2(7)$$

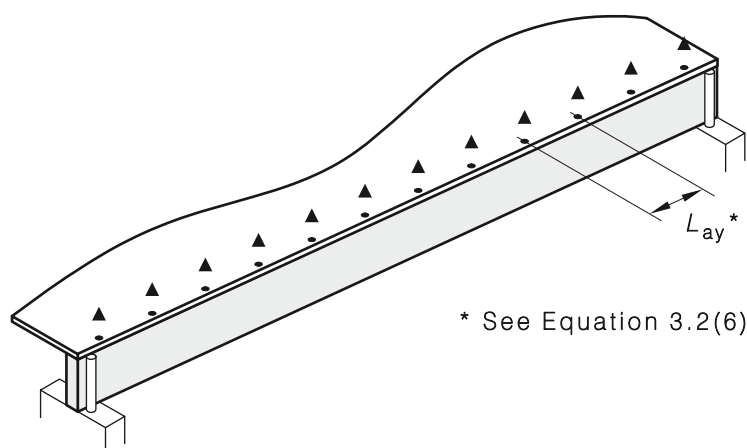


FIGURE 3.5 CONTINUOUS RESTRAINT ALONG THE TENSION EDGE

For a beam that is loaded along its tension edge and, in addition to having a continuous lateral restraint system along its tension edge, has equally spaced torsional restraints at points $L_{a\phi}$ apart, indicated in Figure 3.6, to prevent rotation about the beams Z axis, the slenderness coefficient, denoted by S_1 , is—

$$S_1 = \frac{1.5 d / b}{\left[\left(\frac{\pi d}{L_{a\phi}} \right)^2 + 0.4 \right]^{0.5}} \quad \dots 3.2(8)$$

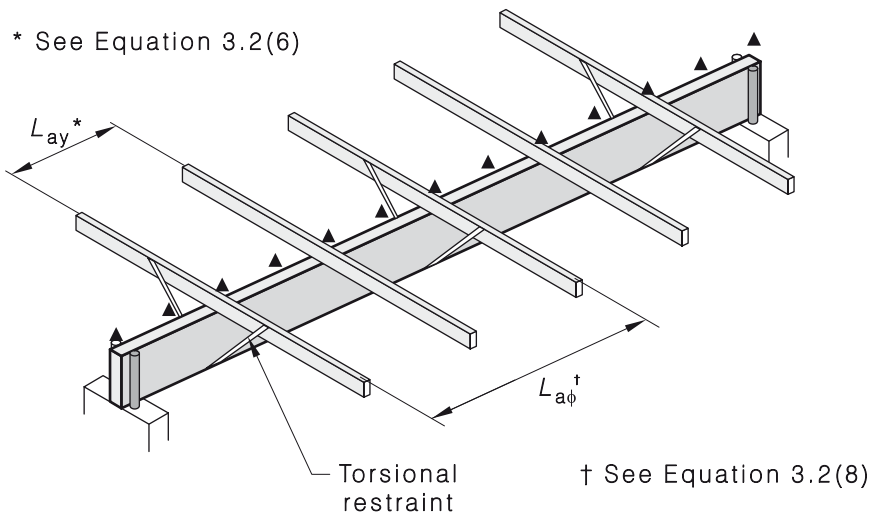


FIGURE 3.6 CONTINUOUS RESTRAINT ALONG THE TENSION EDGE
COMBINED WITH DISCRETE TORSIONAL RESTRAINTS

- (c) *Beams that bend only about their minor axis* For all cases, the slenderness coefficient, denoted by S_2 , is—

$$S_2 = 0.0 \quad \dots 3.2(9)$$

- (d) *Beams that bend about both axes* The design of such beams, described in Clause 3.2.1.2, is based on an interaction of the two special cases for bending about single axis only, and hence no special definition of slenderness is required for this case.

3.2.4 Stability factor

The stability factor (k_{12}) for modification of the characteristic value in bending shall be given by the following:

- (a) For $\rho_b S_1 \leq 10$ —

$$k_{12} = 1.0 \quad \dots 3.2(10)$$

- (b) For $10 \leq \rho_b S_1 \leq 20$ —

$$k_{12} = 1.5 - 0.05 \rho_b S_1 \quad \dots 3.2(11)$$

- (c) For $\rho_b S_1 \geq 20$ —

$$k_{12} = \frac{200}{(\rho_b S_1)^2} \quad \dots 3.2(12)$$

For bending about the minor axis, where S_2 equals 0 then k_{12} equals 1.0.

Conservative values of the material constant (ρ_b) for F-grade, MGP-grade, and A17-grade materials are given in Table 3.1. More accurate values of ρ_b are given by Equations E2(1) and E2(2), Appendix E, and tabulated for F-grades, MGP-grade, and A17-grade in Paragraph E2, Appendix E. The shape of the stability factor curve is illustrated in Figure 3.7.

For material constants for GL-grades and structural laminated veneer lumber, refer to Sections 7 and 8, respectively.

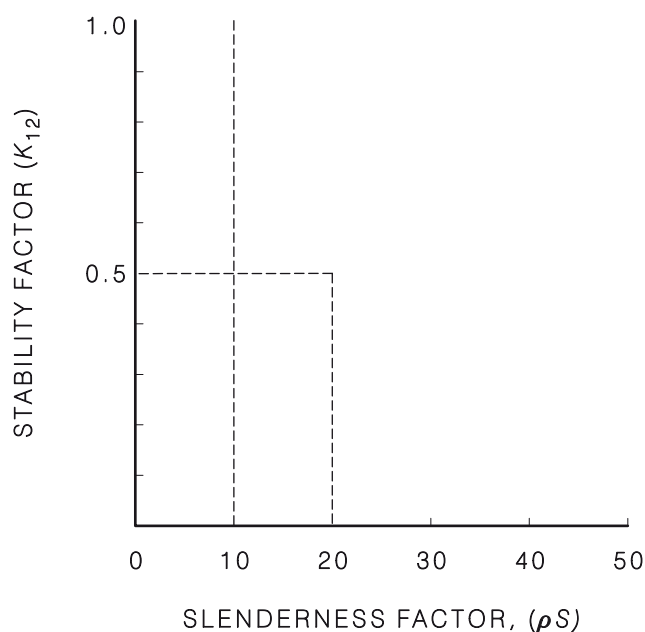


FIGURE 3.7 EFFECT OF SLENDERNESS COEFFICIENT ON THE STABILITY FACTOR FOR BEAMS AND COLUMNS

TABLE 3.1
MATERIAL CONSTANT (ρ_b)
FOR SAWN TIMBER BEAMS

Stress grade	Material constant (ρ_b)	
	Seasoned timber	Unseasoned timber
F34	1.12	1.21
F27	1.08	1.17
F22	1.05	1.15
F17	0.98	1.08
F14	0.98	1.08
F11	0.98	1.07
F8	0.89	0.99
F7	0.86	0.96
F5	0.82	0.91
F4	0.80	0.90
MGP 15	0.91	—
MGP 12	0.85	—
MGP 10	0.75	—
A17	0.95	—

NOTES:

- 1 The values of ρ_b for F-grade seasoned and unseasoned timber correspond to $r = 0.25$ in Tables E1 and E2, Appendix E.
- 2 The values of ρ_b for MGP grades and A17 grade seasoned timber correspond to $r = 0.25$ in Table E1, Appendix E.

3.2.5 Flexural shear strength

The design capacity in shear (V_d) of un-notched beams, for the strength limit state, shall satisfy the following:

$$V_d \geq V^* \quad \dots 3.2(13)$$

where

$$V_d = \phi k_1 k_4 k_6 f'_s A_s \quad \dots 3.2(14)$$

and

V^* = design action effect in shear (see Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

k_1, k_4, k_6 = modification factors given in Section 2

f'_s = characteristic value in shear

A_s = shear plane area (for a rectangular beam loaded about its major axis in bending, $A_s = \frac{2}{3}(bd)$, where b equals the breadth and d equals the depth of the beam).

In calculating the design action effect in shear, it is appropriate to disregard the design actions located within a distance of 1.5 times the depth of the beam from the inside face of the support. This does not apply for the design of notched beams (see Appendix E).

3.2.6 Bearing capacity

3.2.6.1 Design capacity in bearing perpendicular to the grain

The design capacity in bearing perpendicular to the grain ($N_{d,p}$) of a structural element (see Figure 3.8), for strength limit state, shall satisfy the following:

$$N_{d,p} \geq N_p^* \quad \dots 3.2(15)$$

where

$$N_{d,p} = \phi k_1 k_4 k_6 k_7 f'_p A_p \quad \dots 3.2(16)$$

and

ϕ = capacity factor (see Clause 2.3)

N_p^* = design load effect in bearing (see Figure 3.8 and Clause 1.4.2.2)

k_1 to k_7 = modification factors given in Section 2

f'_p = characteristic value in bearing perpendicular to grain

A_p = bearing area for loading perpendicular to grain.

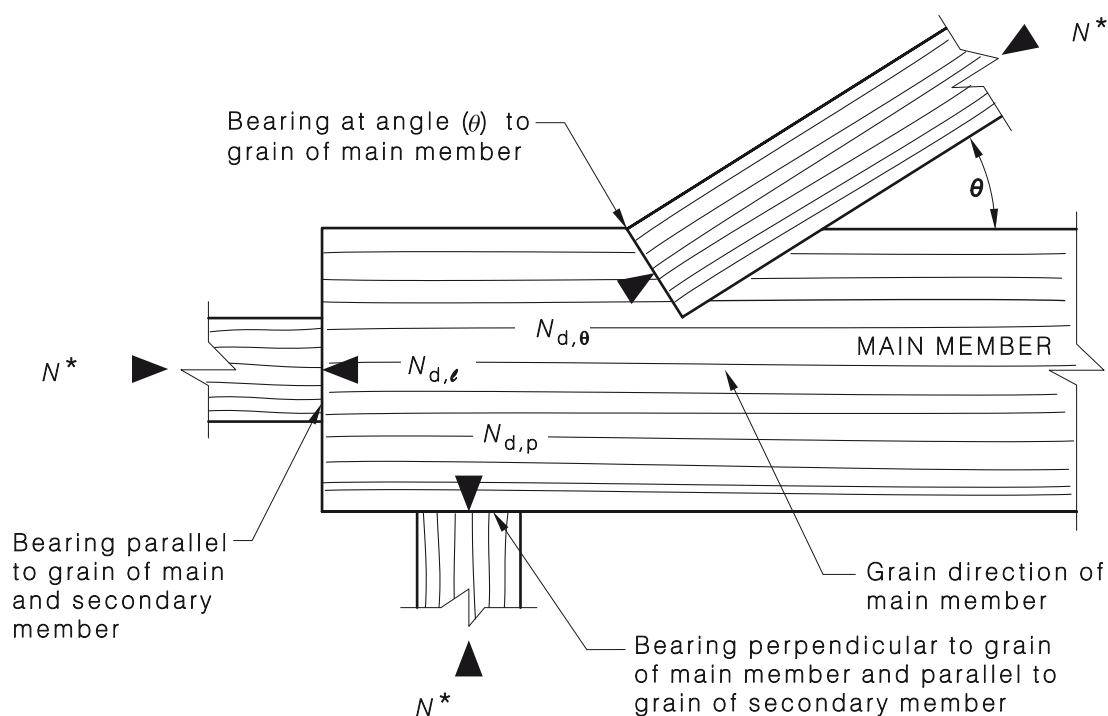


FIGURE 3.8 NOTATION FOR BEARING

3.2.6.2 Design capacity in bearing parallel to grain

The design capacity in bearing parallel to the grain ($N_{d,\ell}$) of a structural element (see Figure 3.8), for strength limit state, shall satisfy the following:

$$N_{d,\ell} \geq N_{\ell}^* \quad \dots 3.2(17)$$

where

$$N_{d,\ell} = \phi k_1 k_4 k_6 f_{\ell}' A_{\ell} \quad \dots 3.2(18)$$

and

N_{ℓ}^* = design load effect in bearing (see Figure 3.8 and Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

k_1, k_4, k_6 = modification factors given in Section 2

f_{ℓ}' = characteristic value in bearing parallel to grain

A_{ℓ} = bearing area for loading parallel to grain

3.2.6.3 Design bearing capacity at an angle to grain

The design capacity ($N_{d,\theta}$) in bearing at an angle (θ) to the grain of wood is given by the following equation:

$$N_{d,\theta} = \frac{N_{d,\ell} N_{d,p}}{N_{d,\ell} \sin^2 \theta + N_{d,p} \cos^2 \theta} \quad \dots 3.2(19)$$

where

$N_{d,\theta}$ = design bearing capacity at an angle to the grain of wood (see Figure 3.8)

$N_{d,\ell}$ = design capacity in bearing parallel to grain (see Clause 3.2.6.2)

$N_{d,p}$ = design capacity in bearing perpendicular to grain (see Clause 3.2.6.1)

3.2.7 Strength of notched beams

Requirements for the design strength in notched beams are given in Appendix E.

3.2.8 Concentrated loads and partial area loads on grid systems

A method to assist in the design of floor grid systems to resist concentrated and partial area loads is given in Appendix E.

3.3 COLUMN DESIGN

3.3.1 Compressive strength

3.3.1.1 Design compressive capacity parallel to grain

The design capacity in compression parallel to the grain ($N_{d,c}$) of un-notched columns, for strength limit state, shall satisfy the following:

$$N_{d,c} \geq N_c^* \quad \dots 3.3(1)$$

where

$$N_{d,c} = \phi k_1 k_4 k_6 k_{12} f'_c A_c \quad \dots 3.3(2)$$

and

N_c^* = design action effect in compression (see Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

k_1, k_4, k_6 = modification factors given in Section 2

k_{12} = stability factor (see Clause 3.3.3)

f'_c = characteristic value in compression parallel to grain

A_c = cross-sectional area of column

3.3.1.2 Buckling about both axes

For columns that can buckle about both axes, the strength limit states shall satisfy the following:

$$N_{d,cx} \geq N_c^* \quad \dots 3.3(3)$$

and

$$N_{d,cy} \geq N_c^* \quad \dots 3.3(4)$$

where

$N_{d,cx}$ and $N_{d,cy}$ = design capacity in compression for buckling about the major x-axis and minor y-axis respectively, determined in accordance with Clauses 3.3.1.1 and 3.3.1.2, respectively

TABLE 3.2
EFFECTIVE LENGTH FACTOR (g_{13})
FOR COLUMNS WITHOUT INTERMEDIATE LATERAL RESTRAINT

Condition of end restraint	Effective length factor (g_{13})
Flat ends	0.7
Restrained at both ends in position and direction	0.7
Each end held by two bolts (substantially restrained)	0.75
One end fixed in position and direction, the other restrained in position only	0.85
Studs in light framing	0.9
Restrained at both ends in position only	1.0
Restrained at one end in position and direction and at the other end partially restrained in direction but not in position	1.5
Restrained at one end in position and direction but not restrained in either position or direction at other end	2.0

NOTE: 'Flat ends' refers to perfectly flat ends bearing on flat unyielding bases.

3.3.2 Slenderness coefficient for lateral buckling under compression

3.3.2.1 General

For the general case, and for several useful specific cases, equations for evaluating the slenderness coefficient are given in Paragraph E4, Appendix E. For the case of solid columns of rectangular cross-section as shown in Figure 3.1, the simple approximations given in Clause 3.3.2.2 are acceptable.

3.3.2.2 Columns of rectangular cross-section

For columns of rectangular cross-section, the slenderness coefficients are as follows:

- (a) *Slenderness coefficient for buckling about the major axis* For the case of discrete restraint systems, the slenderness coefficient, denoted by S_3 , shall be taken to be the lesser of the following:

$$S_3 = \frac{L_{ax}}{d} \quad \dots 3.3(5)$$

and

$$S_3 = \frac{g_{13} L}{d} \quad \dots 3.3(6)$$

where

L_{ax} = distance between points of effectively rigid restraint between which bending about the major (x) axis would be produced by buckling under load (see Figure 3.9)

g_{13} = coefficient given in Table 3.2

For restraint systems that restrain movement in the direction of the y-axis, and are continuous along the length of the column, the slenderness coefficient shall be taken to be—

$$S_3 = 0.0 \quad \dots 3.3(7)$$

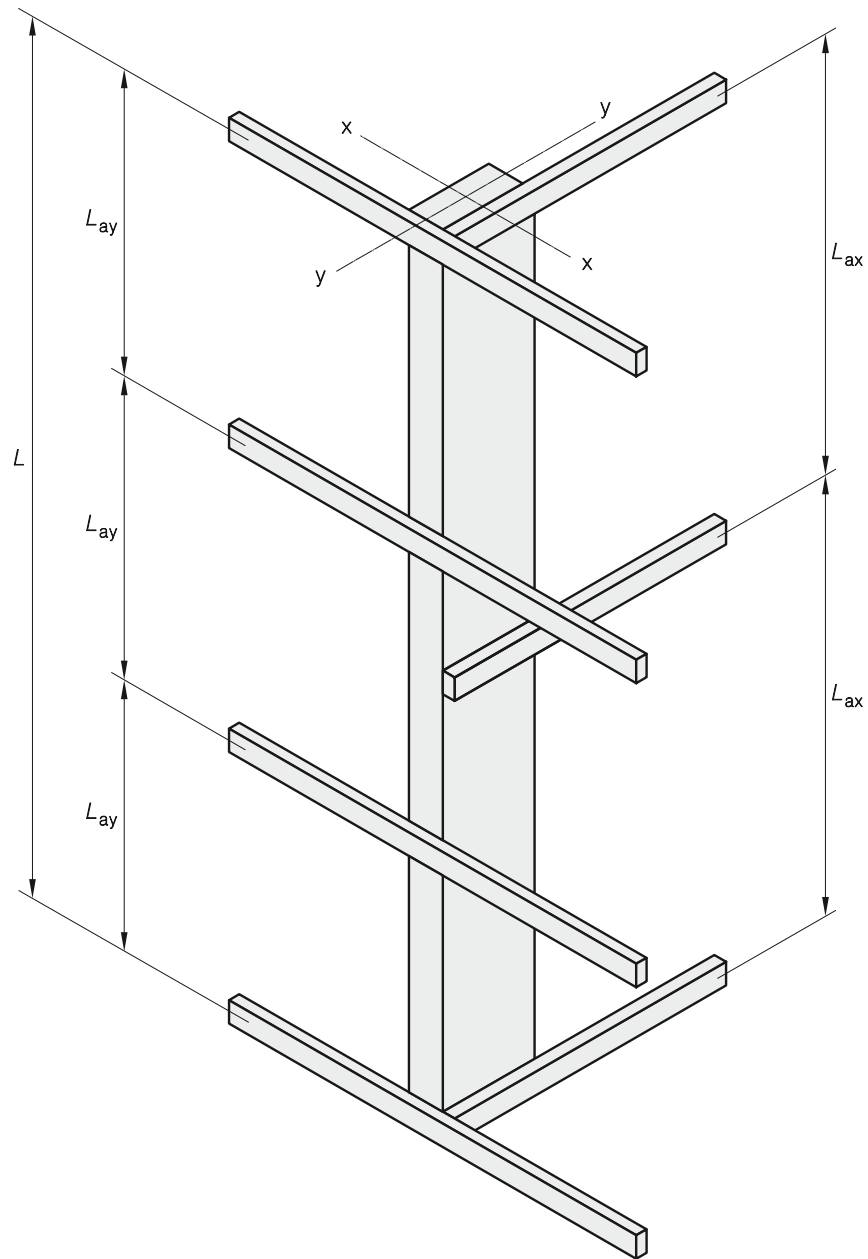


FIGURE 3.9 NOTATION FOR COLUMN RESTRAINTS

- (b) *Slenderness coefficient for buckling about the minor axis* For discrete restraint systems, the slenderness coefficient, denoted by S_4 , shall be taken to be the lesser of the following:

$$S_4 = \frac{L_{ay}}{b} \quad \dots 3.3(8)$$

and

$$S_4 = \frac{g_{13} L}{b} \quad \dots 3.3(9)$$

where

L_{ay} = distance between points of effectively rigid restraint between which bending about the minor (y) axis would be produced by buckling under load (see Figure 3.9)

g_{13} = coefficient given in Table 3.2

For restraint systems that act continuously along one edge only and which restrain movement in the direction of the x -axis, the slenderness coefficient is approximated by the following equation:

$$S_4 = \frac{3.5 d}{b} \quad \dots 3.3(10)$$

- (c) *Columns that can bend about both axes* The design of such columns, described in Clause 3.3.1.2, is based on an interaction of the two special cases for bending about single axes only, and hence no special definition of slenderness is required for this case.

3.3.3 Stability factor

The stability factor (k_{12}) for modification of the characteristic value in compression shall be given by the following:

- (a) For $\rho_c S \leq 10$ —

$$k_{12} = 1.0 \quad \dots 3.3(11a)$$

- (b) For $10 \leq \rho_c S \leq 20$ —

$$k_{12} = 1.5 - 0.05 \rho_c S \quad \dots 3.3(11b)$$

- (c) For $\rho_c S \geq 20$ —

$$k_{12} = \frac{200}{(\rho_c S)^2} \quad \dots 3.3(11c)$$

where

$S = S_3$ for buckling about the major axis

$= S_4$ for buckling about the minor axis

and where a conservative value of the material constant ρ_c is given in Table 3.3; more accurate values of ρ_c are given by Equations E2(3) and E2(4) and tabulated in Tables E3 and E4, Appendix E. The shape of the stability factor curve is illustrated in Figure 3.7.

For material constants for GL-grades and structural laminated veneer lumber, refer to Sections 7 and 8, respectively.

TABLE 3.3
MATERIAL CONSTANT (ρ_c) FOR SAWN TIMBER COLUMNS

Stress grade	Material constant (ρ_c)	
	Seasoned timber	Unseasoned timber
F34	1.17	1.34
F27	1.14	1.31
F22	1.12	1.28
F17	1.08	1.25
F14	1.05	1.21
F11	1.02	1.18
F8	1.00	1.16
F7	0.92	1.08
F5	0.91	1.07
F4	0.87	1.02
MGP 15	0.99	—
MGP 12	0.98	—
MGP 10	0.96	—
A17	1.10	—

NOTES:

- 1 The values of ρ_c for F-grade seasoned and unseasoned timber correspond to $r = 0.25$ in Tables E3 and E4, Appendix E, respectively.
- 2 The values of ρ_c for MGP grades and A17 grade seasoned timber correspond to $r = 0.25$ in Table E3, Appendix E.

3.3.4 Strength of notched columns

The appropriate design procedure for notched columns shall be as given in Appendix E.

3.3.5 Spaced columns

The slenderness coefficients required for computing the design axial strength of spaced columns shall be as given in Appendix E.

3.4 TENSION MEMBER DESIGN

3.4.1 Design tensile capacity parallel to grain

The design capacity in tension parallel to grain ($N_{d,t}$) of un-notched tension members, for strength limit state, shall satisfy the following:

$$N_{d,t} \geq N_t^* \quad \dots 3.4(1)$$

where

$$N_{d,t} = \phi k_1 k_4 k_6 f'_t A_t \quad \dots 3.4(2)$$

N_t^* = design action effect in tension parallel to grain (see Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

k_1 to k_6 = modification factors given in Section 2

f'_t = characteristic value in tension parallel to grain

A_t = net cross-sectional area of tension member

The appropriate design procedure for the design of notched tension members is given in Appendix E.

3.4.2 Design capacity in tension perpendicular to grain

The design capacity in tension perpendicular to grain ($N_{d,tp}$) of un-notched members, for strength limit, shall satisfy the following:

$$N_{d,tp} \geq N_p^* \quad \dots 3.4(3)$$

where

$$N_{d,tp} = \phi k_1 k_{11} f'_{tp} A_{tp} \quad \dots 3.4(4)$$

and

N_{tp}^* = design action effect produced by strength limit states design loads (tension perpendicular to grain) (see Clause 1.4.2.2)

ϕ = capacity factor (see Clause 2.3)

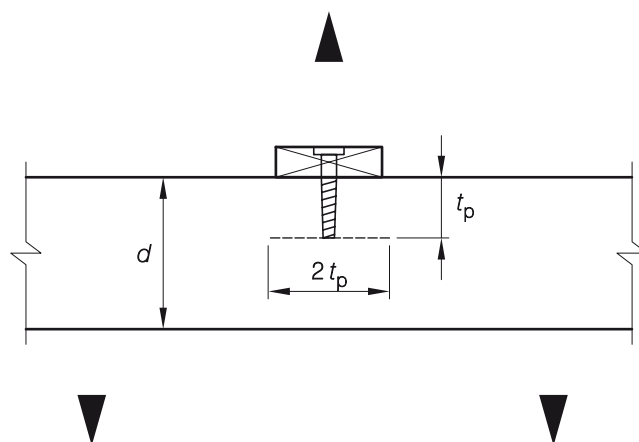
k_1 = modification factors for duration of load, given in Section 2

k_{11} = modification factors for the effect of volume = $(V_o/V)^{0.2}$

where $V_o = 10^7$ (a reference volume) and V is the volume, in mm^3 , stressed in tension perpendicular to the grain at a level of stress greater than 80% of the maximum stress

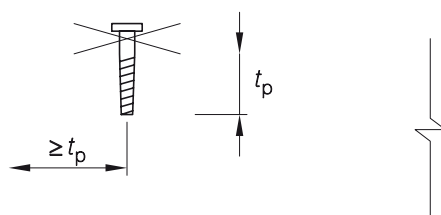
f'_{tp} = characteristic value in tension perpendicular to grain

A_{tp} = member width (thickness) by effective length stressed in tension (see Figure 3.10), which is the effective area resisting tension perpendicular to the grain



Effective length = $2t_p$

(a) Fixed at one point



(b) Minimum end distance

FIGURE 3.10 EFFECTIVE LENGTH STRESSED IN TENSION PERPENDICULAR TO GRAIN

3.5 COMBINED BENDING AND AXIAL ACTIONS

3.5.1 Combined bending and compression

Rectangular members with cross-section as shown in Figure 3.1 subject to combined axial compression and bending about the x-axis only, shall be proportioned so that—

$$\left(\frac{M_x^*}{M_{d,x}} \right)^2 + \frac{N_c^*}{N_{d,cy}} \leq 1 \quad \dots 3.5(1)$$

and

$$\frac{M_x^*}{M_{d,x}} + \frac{N_c^*}{N_{d,cx}} \leq 1 \quad \dots 3.5(2)$$

where

M_x^* = design action effect in bending about the major principal x-axis

$M_{d,x}$ = design capacity in bending about the major principal x-axis (see Clause 3.2.1.1)

N_c^* = design action effect in compression, (see Clause 1.4.2.2)

$N_{d,cx}$ = design capacity in compression for buckling about the x-axis.

$N_{d,cy}$ = design capacity in compression for buckling about the y-axis

NOTE: Equations 3.5(1) and 3.5(2) contain an allowance for the effect of bending moment amplification due to the axial load. For non-rectangular members, Equations 3.5(1) and 3.5(2) may be used in the absence of other information.

For the unusual case of a beam-column subjected to bending simultaneously about both the x- and y-axes, a conservative criterion of strength is given in Appendix E.

3.5.2 Combined bending and tension

For a rectangular member subject to combined bending and tension, action effects shall be proportioned so that—

$$\frac{k_{12} M^*}{M_d} + \frac{N_t^*}{N_{d,t}} \leq 1 \quad \dots 3.5(3)$$

and

$$\frac{M_x^*}{M_{d,x}} - \frac{Z}{A} \frac{N_t^*}{M_{d,x}} \leq 1 \quad \dots 3.5(4)$$

where

k_{12} = stability factor used in bending strength calculation (see Clause 3.2.4)

M^* = design action effect in bending about the appropriate axis (see Clause 1.4.2.2)

M_d = design capacity in bending about the appropriate axis (see Clause 3.2.1.1)

N_t^* = design action effect in tension (see Clause 1.4.2.2)

$N_{d,t}$ = design capacity of a member in tension (see Clause 3.4.1)

M_x^* = design action effect in bending about the major principal axis (see Clause 3.2.1.1)

$M_{d,x}$ = design capacity in bending about the major principal axis (see Clause 3.2.1.1)

Z = section modulus about the appropriate axis

A = cross-sectional area.

SECTION 4 DESIGN CAPACITY OF JOINTS IN TIMBER STRUCTURES

4.1 GENERAL

4.1.1 Scope of Section

This Section applies to joints in solid timber fabricated with mechanical fasteners and characterized by a long history of use in timber structures. These include joints fabricated with the following mechanical fasteners:

- (a) Nails.
- (b) Wood screws.
- (c) Bolts.
- (d) Coach screws.
- (e) Split-ring fasteners.
- (f) Shear-plate fasteners.

Joints with plywood and the calculation of characteristic capacities for bolts are covered in Appendix C.

NOTES:

- 1 Appendix C gives further information on joints.
- 2 Testing of specialized and patented mechanical fasteners and variants of conventional fasteners is specified in AS 1649.
- 3 This Standard does not specifically cover glued timber-to-timber or timber-to-plywood connections as occur in fabricated components such as stressed skin panels or plywood webbed beams. In such cases, joint design may be based on the timber components in the connection, provided the joint is fabricated using a rigid, durable adhesive. Phenolic type adhesives meet these requirements. The design of fabricated components comprising glued connections is therefore based on the fact that with correct bonding practice and quality control, a joint is developed in which the adhesive bond strength and durability will be superior to the timber components comprising the joint.
- 4 Information on methods for assessing the deformation of joints is given in Paragraph C3, Appendix C.

4.1.2 Joint groups

For the purpose of joint design, timber species have been classified into six joint groups: J1, J2, J3, J4, J5 and J6 for unseasoned timber, and JD1, JD2, JD3, JD4, JD5 and JD6 for seasoned timber. The joint group classifications for timber species and moisture condition shall be as listed in Tables H2.3 and H2.4, Appendix H.

The joint group appropriate for the calculation of the design capacity of the joint shall be determined such that—

- (a) where a joint comprises more than one species of timber, the species with the lowest joint group classification shall be used to calculate the capacity of the joint; except
- (b) where the capacity of each part of the joint can be determined independently, it is permissible to calculate the design capacity of the joint as the lesser of the capacities of the individual parts based upon their individual joint group classification.

4.1.3 Joint types

For the purpose of joint design, joints are classified into two types as follows:

- (a) *Type 1 joint* Fasteners subject to shear loads where the fastener is into the side or end grain of connected members (see Figure 4.1 and Figures 4.2(a) and 4.2(b)).
- (b) *Type 2 joint* Fasteners subject to axial loads where the fastener is installed into the side or end grain of connected members (see Figure 4.1 and Figures 4.4(a), 4.4(b), and 4.4(c)).

NOTE: Where timber elements experience tension perpendicular to the grain, reference should be made to Clause 3.4.2.

Design capacities for Type 1 and Type 2 joints of various configurations are given in Clauses 4.2 to 4.7.

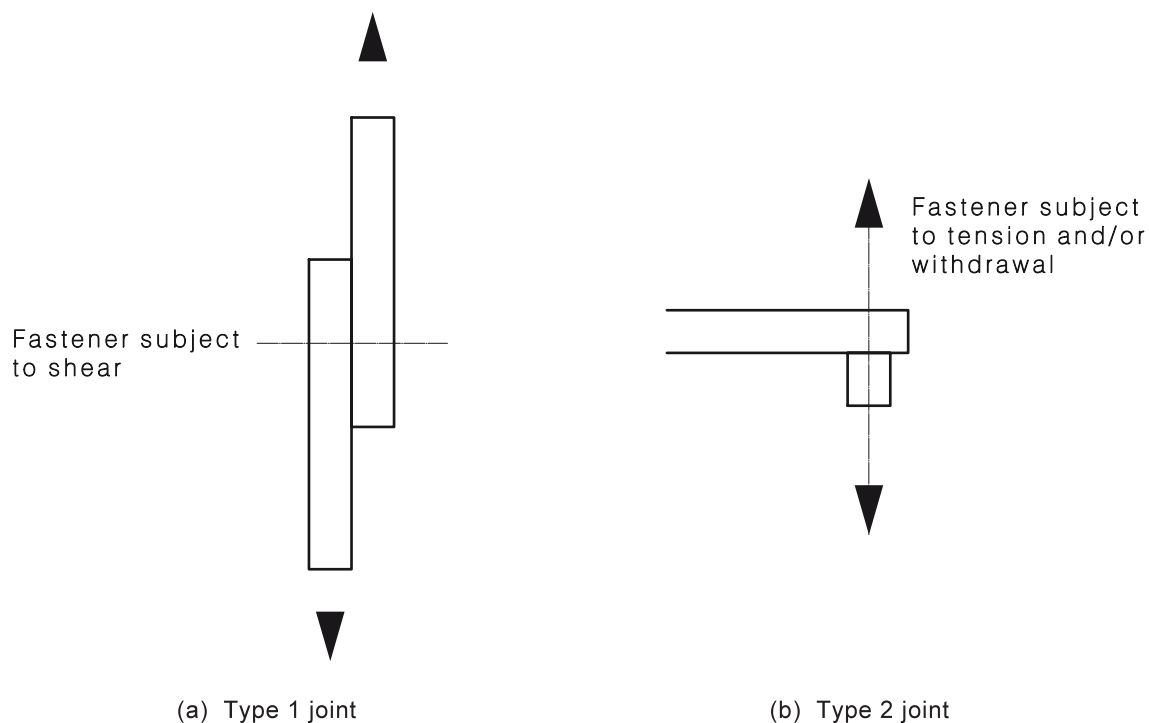


FIGURE 4.1 JOINT TYPES

4.1.4 Strength-reducing characteristics at joints

The characteristic capacities for fasteners in timber given in this Standard do not include any allowance for the presence of strength-reducing characteristics in the vicinity of the fastener. Fasteners shall be placed at locations where there are no significant strength-reducing characteristics or appropriate reductions shall be made to the capacity of the joint. Where joints are made in timber containing corewood, the characteristic capacities for fasteners shall be taken to correspond to the next lowest joint group to that assigned to the species of timber free of corewood.

4.1.5 Tendency to split

Special precautions shall be specified in the use of timber that has a tendency to split to an extent that is detrimental to fastener strength (see Clauses 4.2.4 and 4.2.6). In the absence of other guidance, the criterion for tendency to split shall be based on the parameter α defined by the following equation:

$$\alpha = \varepsilon^2 / \gamma \quad \dots 4.1(1)$$

where

ε = tangential shrinkage, in percentage

γ = tangential cleavage strength of unseasoned timber, in newtons per millimetre, as measured by BS 373 or ASTM D143

Species for which $\alpha > 0.8$ often have a high tendency to split, particularly in exposed locations; species for which $\alpha < 0.55$ usually have little tendency to split.

NOTES:

- 1 Most eucalypt and corymbia species and most hardwood species of dry sclerophyll forests that have a basic density of less than 700 kg/m^3 have a splitting parameter $\alpha > 0.8$; most softwoods and most rainforest hardwoods have a splitting parameter $\alpha < 0.8$.
- 2 Information on shrinkage and cleavage strength for specific species can be obtained from the following:
 - (a) KINGSTON, R.S.T. and RISDON, C.J.E. *Shrinkage and Density of Australian and other South-west Pacific Woods*. Division of Forest Products Technological Paper No. 13, CSIRO, 1961.
 - (b) BUDGEN, B. *Shrinkage and Density of some Australian and South-east Asian Timbers*. Division of Building Research Technological Paper (Second Series) No. 38, CSIRO, 1981.
 - (c) BOLZA, E. and KLOOT, N.H. *The Mechanical Properties of 174 Australian Timbers*. Division of Forest Products Technological Paper No. 25, CSIRO, 1963.

4.1.6 Eccentric joints

When it is impracticable to ensure that all the members meeting at a joint are arranged symmetrically, with their centre-lines intersecting on a common axis, which is also the axis of resistance of the fastener or group of fasteners, the combined effects of primary stresses and secondary stresses due to the resulting bending and shear stress shall be checked.

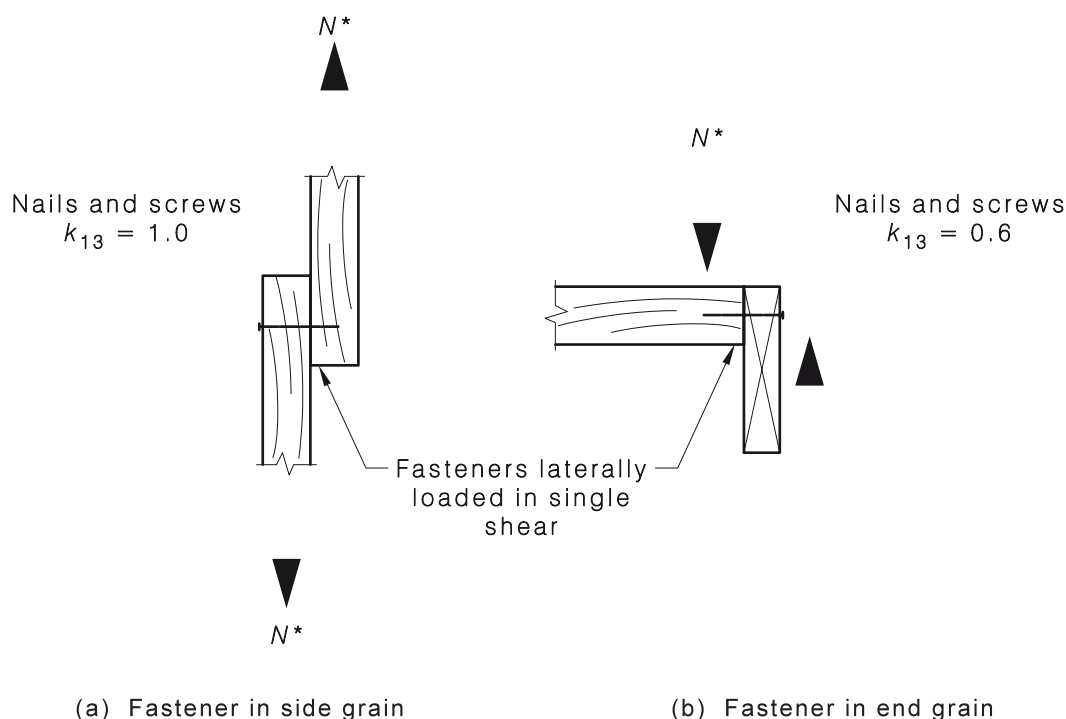


FIGURE 4.2 TYPE 1 JOINTS FOR NAILS AND SCREWS LOADED IN SHEAR

4.2 DESIGN OF NAILED JOINTS

4.2.1 General

The characteristic capacities for nails, listed in Tables 4.1 and 4.2, apply to plain shank low carbon steel nails, as specified in AS 2334.

4.2.2 Characteristic capacities for nails

4.2.2.1 General

The characteristic capacities for nails are applicable for load directions at any angle to the grain (see Figure 4.3) and are given in Clauses 4.2.2.2 to 4.2.2.3.

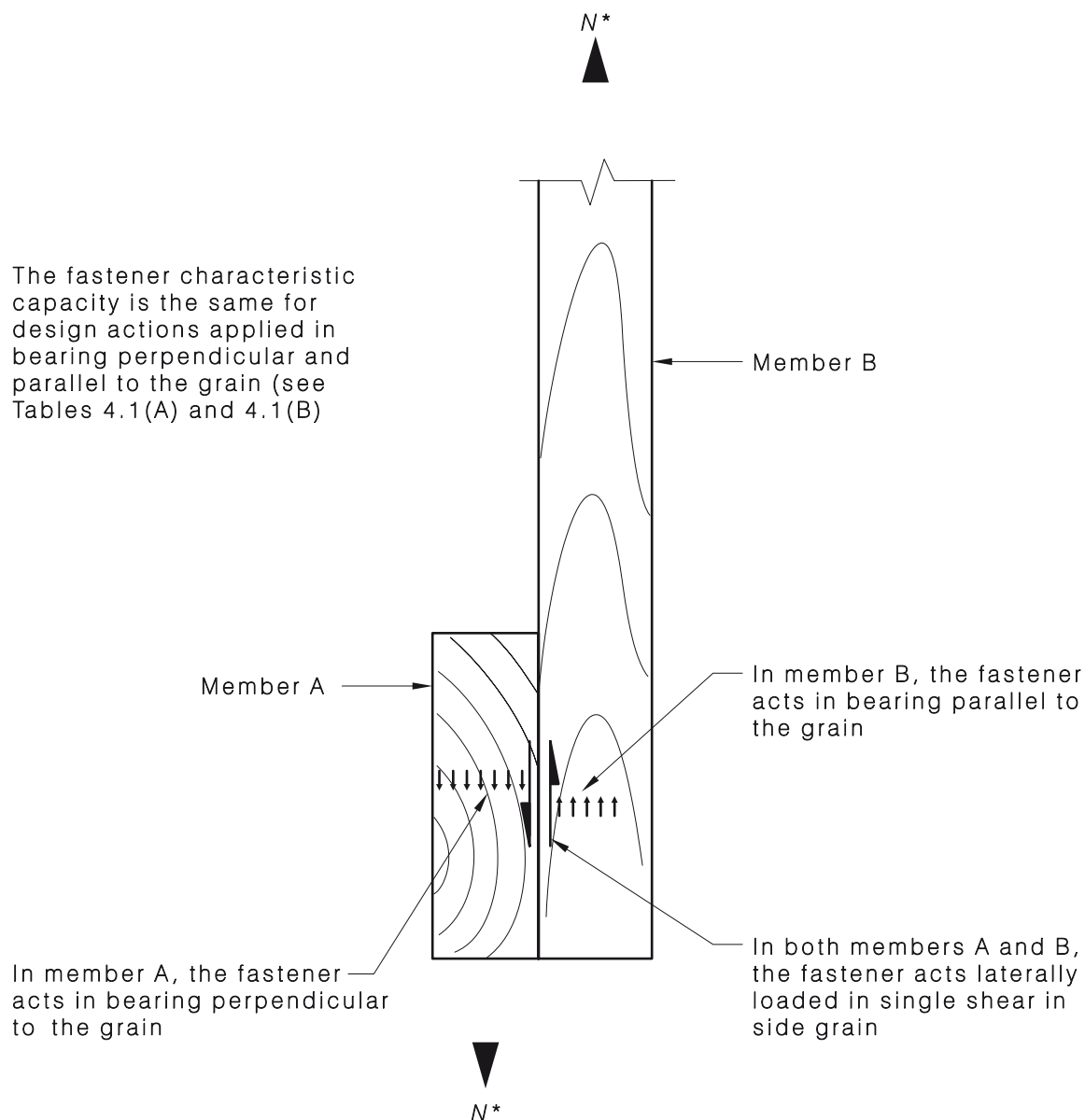


DIAGRAM ILLUSTRATES A TYPE 1 JOINT

FIGURE 4.3 FASTENER (NAIL OR SCREW) IN BEARING PERPENDICULAR AND PARALLEL TO THE GRAIN

4.2.2.2 Type 1 joints

Characteristic capacities for Type 1 joints are as follows:

- (a) *Lateral loads in side grain (see Figure 4.2(a))* The characteristic capacities for nails, whether hand or machine driven, laterally loaded in single shear in the side grain of unseasoned timber are given in Table 4.1(A) and in seasoned timber are given in Table 4.1(B).
- (b) *Lateral loads in end grain (see Figure 4.2(b))* The characteristic capacities for nails, whether hand or machine driven, laterally loaded in single shear in the end grain of unseasoned and seasoned timber shall be taken as 60% of the values given in Tables 4.1(A) and 4.1(B), respectively.

NOTE: The modification factor k_{13} accounts for end grain effects in Equations 4.2(2) and 4.2(4) (see Clause 4.2.3.2 and 4.2.3.3).

TABLE 4.1(A)
CHARACTERISTIC CAPACITY (Q_k)—SINGLE PLAIN
SHANK STEEL NAIL LATERALLY LOADED IN
SINGLE SHEAR IN SIDE GRAIN—UNSEASONED TIMBER

Species group	Characteristic capacity per nail, N						
	Nail diameter, mm						
	2.5	2.8	3.15	3.75	4.5	5.0	5.6
J1	975	1180	1445	1960	2700	3245	3955
J2	765	930	1135	1550	2125	2565	3125
J3	545	665	810	1105	1520	1830	2225
J4	385	470	575	780	1075	1300	1595
J5	295	355	445	590	810	975	1180
J6	220	265	325	445	620	740	885

TABLE 4.1(B)
CHARACTERISTIC CAPACITY (Q_k)—SINGLE PLAIN
SHANK STEEL NAIL LATERALLY LOADED IN SINGLE
SHEAR IN SIDE GRAIN— SEASONED TIMBER

Species group	Characteristic capacity per nail, N						
	Nail diameter, mm						
	2.5	2.8	3.15	3.75	4.5	5.0	5.6
JD1	1285	1565	1920	2610	3570	4310	5250
JD2	975	1180	1445	1960	2700	3245	3955
JD3	765	930	1135	1550	2125	2565	3125
JD4	545	665	810	1110	1520	1830	2225
JD5	445	545	680	915	1255	1505	1830
JD6	340	415	500	695	945	1135	1385

NOTE: See Clause 4.2.5 for nail length and timber thicknesses.

4.2.2.3 Type 2 joints

Characteristic capacities for Type 2 joints are as follows:

- (a) *Withdrawal loads from side grain (see Figure 4.4(a))* The characteristic capacities for nails, driven by hand only, in withdrawal from the side grain of unseasoned timber are given in Table 4.2(A) and in seasoned timber are given in Table 4.2(B).

NOTE: Withdrawal loads for gun-driven plain shank nails may be considerably less than withdrawal loads for the same nails driven by hand.

- (b) *Withdrawal loads from end grain (see Figure 4.4(b))* The characteristic capacities for nails, driven by hand only, axially loaded in withdrawal from the end grain of unseasoned and seasoned timber, shall not exceed 25% of the values given in Tables 4.2(A) and 4.2(B) respectively. A minimum of two nails shall be used in end grain of Type 2 joints.

For skew driven nails (see Figure 4.4(c)), the characteristic capacities for nails in withdrawal from the end grain of unseasoned and seasoned timber shall not exceed 60% of the values given in Tables 4.2(A) and 4.2(B) respectively. A minimum of two (oppositely driven) nails shall be used in end grain of Type 2 joints.

NOTE: The modification factor (k_{13}) accounts for end grain effects in Equation 4.2(6) (see Clause 4.2.3.4).

TABLE 4.2(A)

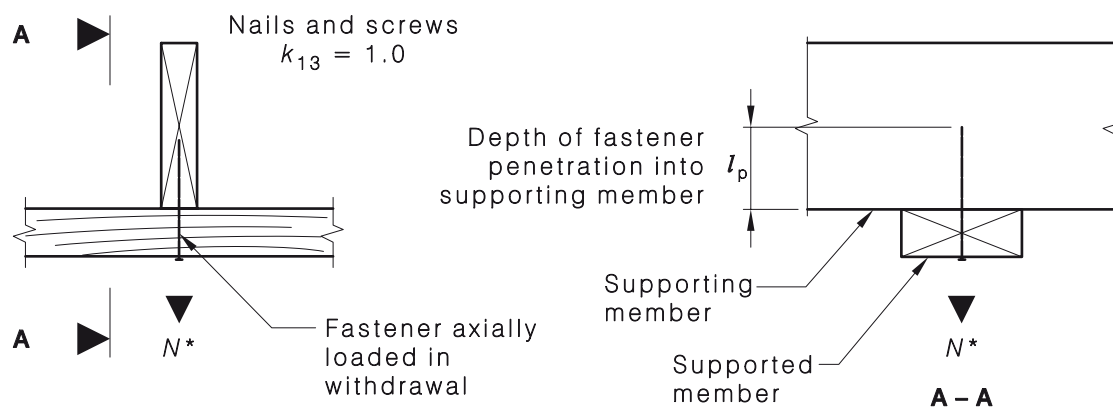
**CHARACTERISTIC CAPACITY (Q_k)—SINGLE PLAIN SHANK
STEEL NAIL IN WITHDRAWAL AXIALLY LOADED
IN SIDE GRAIN—UNSEASONED TIMBER**

Species group	Characteristic capacity, N per mm penetration of nail						
	Nail diameter, mm						
	2.5	2.8	3.15	3.75	4.5	5.0	5.6
J1	19	20	24	27	32	35	41
J2	15	17	19	22	27	30	34
J3	13	14	16	19	24	25	29
J4	11	13	14	17	20	22	25
J5	9.1	10	11	14	17	19	20
J6	6.8	7.6	8.6	10	12	14	15

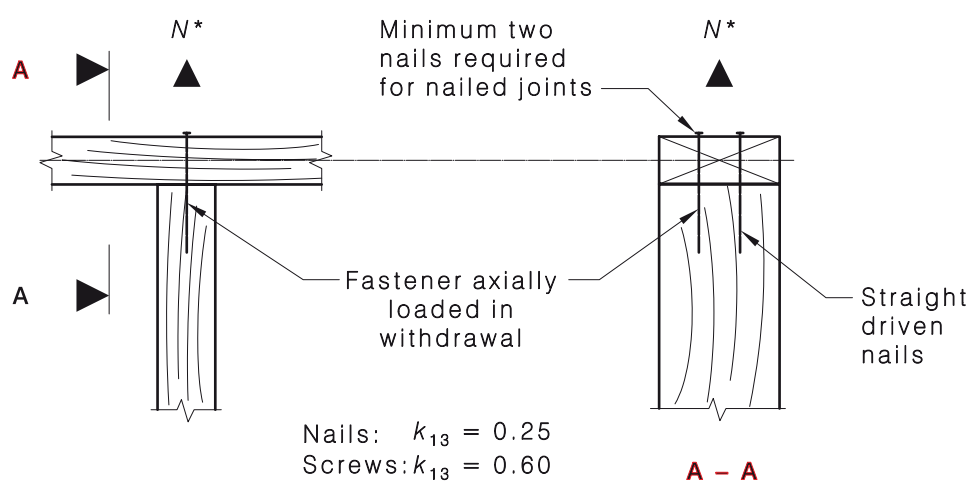
TABLE 4.2(B)

**CHARACTERISTIC CAPACITY (Q_k)—SINGLE PLAIN SHANK
STEEL NAIL IN WITHDRAWAL AXIALLY LOADED
IN SIDE GRAIN—SEASONED TIMBER**

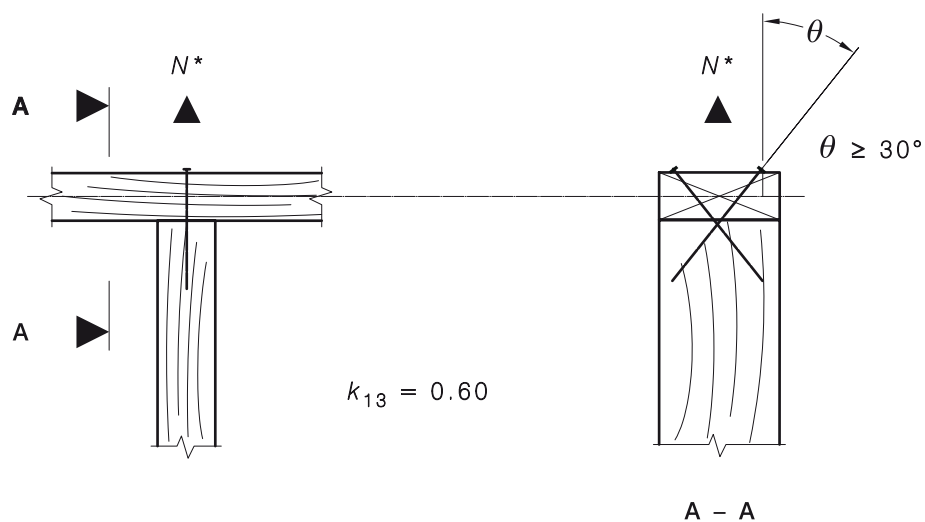
Species group	Characteristic capacity, N per mm penetration of nail						
	Nail diameter, mm						
	2.5	2.8	3.15	3.75	4.5	5.0	5.6
JD1	29	32	35	42	51	57	64
JD2	20	22	25	29	35	39	44
JD3	13	14	16	19	24	25	29
JD4	8.3	9.3	10	13	15	17	19
JD5	5.2	5.9	6.6	7.9	9.5	11	12
JD6	3.7	4.2	4.7	5.6	6.8	7.6	8.5



(a) Fastener in side grain



(b) Fastener in end grain



(c) Skew driven nails in end grain

NOTE: Flat-head nails should be used where head pull-through may otherwise precede withdrawal and limit axial load carrying capacity; this is more likely with softwoods and lower density hardwoods.

FIGURE 4.4 TYPE 2 JOINTS FOR NAILS AND SCREWS (AND COACH SCREWS) LOADED IN WITHDRAWAL