

# *The European Union*

## **EDICT OF GOVERNMENT**

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EN 1995-1-1 (2004) (English): Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]



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EUROPEAN STANDARD  
NORME EUROPÉENNE  
EUROPÄISCHE NORM

**EN 1995-1-1:2004+A1**

June 2008

ICS 91.010.30; 91.080.20

Incorporating corrigendum June 2006  
Supersedes ENV 1995-1-1:1993

English version

## Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings

Eurocode 5: Conception et calcul des structures en bois -  
Partie 1-1 : Généralités - Règles communes et règles pour  
les bâtiments

Eurocode 5: Bemessung und Konstruktion von Holzbauten  
- Teil 1-1: Allgemeines - Allgemeine Regeln und Regeln für  
den Hochbau

This European Standard was approved by CEN on 16 April 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



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## Foreword

This European Standard EN 1995-1-1 has been prepared by Technical Committee CEN/TC250 "Structural Eurocodes", the Secretariat of which is held by BSI.

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by March 2010.

This European Standard supersedes ENV 1995-1-1:1993.

CEN/TC250 is responsible for all Structural Eurocodes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

## Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement<sup>1</sup> between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links de facto the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products – CPD – and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990:2002	Eurocode: Basis of Structural Design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993	Eurocode 3: Design of steel structures
EN 1994	Eurocode 4: Design of composite steel and concrete structures
EN 1995	Eurocode 5: Design of timber structures
EN 1996	Eurocode 6: Design of masonry structures
EN 1997	Eurocode 7: Geotechnical design

<sup>1</sup> Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

EN 1998	Eurocode 8: Design of structures for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

### **Status and field of application of Eurocodes**

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;
- as a basis for specifying contracts for construction works and related engineering services ;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents<sup>2</sup> referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards<sup>3</sup>. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

### **National Standards implementing Eurocodes**

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e.:

- values and/or classes where alternatives are given in the Eurocode;
- values to be used where a symbol only is given in the Eurocode;
- country specific data (geographical, climatic, etc.), e.g. snow map;

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<sup>2</sup> According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

<sup>3</sup> According to Art. 12 of the CPD the interpretative documents shall:  
give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;  
indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;  
serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

- the procedure to be used where alternative procedures are given in the Eurocode;
- decisions on the application of informative annexes;
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

### **Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products**

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works<sup>4</sup>. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes shall clearly mention which Nationally Determined Parameters have been taken into account.

### **Additional information specific to EN 1995-1-1**

EN 1995 describes the Principles and requirements for safety, serviceability and durability of timber structures. It is based on the limit state concept used in conjunction with a partial factor method.

For the design of new structures, EN 1995 is intended to be used, for direct application, together with EN 1990:2002 and relevant Parts of EN 1991.

Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies. When EN 1995-1-1 is used as a base document by other CEN/TCs the same values need to be taken.

### **National annex for EN 1995-1-1**

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1995-1-1 should have a National annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed in EN 1995-1-1 through clauses:

2.3.1.2(2)P	Assignment of loads to load-duration classes;
2.3.1.3(1)P	Assignment of structures to service classes;
2.4.1(1)P	Partial factors for material properties;
6.1.7(2)	Shear;
6.4.3(8)	Double tapered, curved and pitched cambered beams;
7.2(2)	Limiting values for deflections;
7.3.3(2)	Limiting values for vibrations;
8.3.1.2(4)	Nailed timber-to-timber connections: Rules for nails in end grain;
8.3.1.2(7)	Nailed timber-to-timber connections: Species sensitive to splitting;
9.2.4.1(7)	Design method for wall diaphragms;
9.2.5.3(1)	Bracing modification factors for beam or truss systems;
10.9.2(3)	Erection of trusses with punched metal plate fasteners: Maximum bow;
10.9.2(4)	Erection of trusses with punched metal plate fasteners: Maximum deviation.

## **Foreword to amendment A1**

This document (EN 1995-1-1:2004/A1:2008) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This Amendment to the European Standard EN 1995-1-1:2004 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2008, and conflicting national standards shall be withdrawn at the latest by March 2010.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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<sup>4</sup> see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

## **Section 1 General**

### **1.1 Scope**

#### **1.1.1 Scope of EN 1995**

(1)P EN 1995 applies to the design of buildings and civil engineering works in timber (solid timber, sawn, planed or in pole form, glued laminated timber or wood-based structural products, e.g. LVL) or wood-based panels jointed together with adhesives or mechanical fasteners. It complies with the principles and requirements for the safety and serviceability of structures and the basis of design and verification given in EN 1990:2002.

(2)P EN 1995 is only concerned with requirements for mechanical resistance, serviceability, durability and fire resistance of timber structures. Other requirements, e.g concerning thermal or sound insulation, are not considered.

(3) EN 1995 is intended to be used in conjunction with:  
EN 1990:2002 Eurocode – Basis of design  
EN 1991 “Actions on structures”  
EN’s for construction products relevant to timber structures  
EN 1998 “Design of structures for earthquake resistance”, when timber structures are built in seismic regions

(4) EN 1995 is subdivided into various parts:  
EN 1995-1 General  
EN 1995-2 Bridges

(5) EN 1995-1 “General” comprises:  
EN 1995-1-1 General – Common rules and rules for buildings  
EN 1995-1-2 General rules – Structural Fire Design

(6) EN 1995-2 refers to the common rules in EN 1995-1-1. The clauses in EN 1995-2 supplement the clauses in EN 1995-1.

#### **1.1.2 Scope of EN 1995-1-1**

(1) EN 1995-1-1 gives general design rules for timber structures together with specific design rules for buildings.

(2) The following subjects are dealt with in EN 1995-1-1:

- Section 1: General
- Section 2: Basis of design
- Section 3: Material properties
- Section 4: Durability

- Section 5: Basis of structural analysis
- Section 6: Ultimate limit states
- Section 7: Serviceability limit states
- Section 8: Connections with metal fasteners
- Section 9: Components and assemblies
- Section 10: Structural detailing and control.

(3)P EN 1995-1-1 does not cover the design of structures subject to prolonged exposure to temperatures over 60°C.

## 1.2 Normative references

**A1** (1) This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ISO standards:

- ISO 2081 Metallic coatings. Electroplated coatings of zinc on iron or steel
- ISO 2631-2:1989 Evaluation of human exposure to whole-body vibration. Part 2: Continuous and shock-induced vibrations in buildings (1 to 80 Hz)

European Standards:

- EN 300 Oriented Strand Board (OSB) – Definition, classification and specifications
- EN 301 Adhesives, phenolic and aminoplastic for load-bearing timber structures; Classification and performance requirements
- EN 312 Particleboards – Specifications
- EN 335-1 Durability of wood and wood-based products – definition of hazard classes of biological attack – Part 1: General
- EN 335-2 Durability of wood and wood-based products – definition of hazard classes of biological attack – Part 2: Application to solid wood
- EN 335-3 Durability of wood and wood-based products – Definition of hazard classes of biological attack – Part 3: Application to wood-based panels
- EN 350-2 Durability of wood and wood-based products – Natural durability of solid wood – Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe
- EN 351-1 Durability of wood and wood-based products – Preservative treated solid wood – Part 1: Classification of preservative penetration and retention
- EN 383 Timber structures – Test methods – Determination of embedding strength and foundation values for dowel type fasteners
- EN 385 Finger jointed structural timber – Performance requirements and minimum production requirements
- EN 387 Glued laminated timber – Large finger joints – Performance requirements and minimum production requirements
- EN 409 Timber structures – Test methods. Determination of the yield moment of dowel type fasteners – Nails **A1**

EN 460	Durability of wood and wood-based products – Natural durability of solid wood – Guide of the durability requirements for wood to be used in hazard classes
EN 594	Timber structures – Test methods – Racking strength and stiffness of timber frame wall panels
EN 622-2	Fibreboards – Specifications. Part 2: Requirements for hardboards
EN 622-3	Fibreboards – Specifications. Part 3: Requirements for medium boards
EN 622-4	Fibreboards – Specifications. Part 4: Requirements for softboards
EN 622-5	Fibreboards – Specifications. Part 5: Requirements for dry process boards (MDF)
EN 636	Plywood – Specifications
EN 912	Timber fasteners – Specifications for connectors for timber
EN 1075	Timber structures – Test methods – Testing of joints made with punched metal plate fasteners
EN 1380	Timber structures – Test methods – Load bearing nailed joints
EN 1381	Timber structures – Test methods – Load bearing stapled joints
EN 1382	Timber structures – Test methods – Withdrawal capacity of timber fasteners
EN 1383	Timber structures – Test methods – Pull through testing of timber fasteners
EN 1990:2002	Eurocode – Basis of structural design
EN 1991-1-1	Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight and imposed loads
EN 1991-1-3	Eurocode 1: Actions on structures – Part 1-3: General actions – Snow loads
EN 1991-1-4	Eurocode 1: Actions on structures – Part 1-4: General actions – Wind loads
EN 1991-1-5	Eurocode 1: Actions on structures – Part 1-5: General actions – Thermal actions
EN 1991-1-6	Eurocode 1: Actions on structures – Part 1-6: General actions – Actions during execution
EN 1991-1-7	Eurocode 1: Actions on structures – Part 1-7: General actions – Accidental actions due to impact and explosions
EN 10147	Specification for continuously hot-dip zinc coated structural steel sheet and strip – Technical delivery conditions
EN 13271	Timber fasteners – Characteristic load-carrying capacities and slip moduli for connector joints
EN 13986	Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking
EN 14080	Timber structures – Glued laminated timber – Requirements
EN 14081-1	Timber structures – Strength graded structural timber with rectangular cross-section – Part 1, General requirements
EN 14250	Timber structures – Production requirements for fabricated trusses using punched metal plate fasteners
EN 14279	Laminated veneer lumber (LVL) – Specifications, definitions, classification and requirements <span style="border: 1px solid black; padding: 0 2px;">A1</span>

EN 14358	Timber structures – Fasteners and wood-based products – Calculation of characteristic 5-percentile value and acceptance criteria for a sample
EN 14374	Timber structures – Structural laminated veneer lumber – Requirements
EN 14545	Timber structures – Connectors – Requirements
EN 14592	Timber structures – Fasteners – Requirements
EN 26891	Timber structures – Joints made with mechanical fasteners – General principles for the determination of strength and deformation characteristics
EN 28970	Timber structures – Testing of joints made with mechanical fasteners; Requirements for wood density (ISO 8970:1989)

NOTE: As long as EN 14545 and EN 14592 are not available as European standards, more information may be given in the National annex. <sup>(A1)</sup>

### 1.3 Assumptions

(1)P The general assumptions of EN 1990:2002 apply.

(2) Additional requirements for structural detailing and control are given in section 10.

### 1.4 Distinction between Principles and Application Rules

(1)P The rules in EN 1990:2002 clause 1.4 apply.

### 1.5 Terms and definitions

#### 1.5.1 General

(1)P The terms and definitions of EN 1990:2002 clause 1.5 apply.

#### 1.5.2 Additional terms and definitions used in this present standard

##### 1.5.2.1

##### Characteristic value

Refer to EN 1990:2002 subclause 1.5.4.1.

##### 1.5.2.2

##### Dowelled connection

Connection made with a circular cylindrical rod usually of steel, with or without a head, fitting tightly in prebored holes and used for transferring loads perpendicular to the dowel axis.

##### 1.5.2.3

##### Equilibrium moisture content

The moisture content at which wood neither gains nor loses moisture to the surrounding air.

##### 1.5.2.4

##### Fibre saturation point

Moisture content at which the wood cells are completely saturated.

**1.5.2.5**

**LVL**

Laminated veneer lumber, defined according to EN 14279 and EN 14374

**1.5.2.6**

**Laminated timber deck**

A plate made of abutting parallel and solid laminations connected together by nails or screws or prestressing or gluing.

**1.5.2.7**

**Moisture content**

The mass of water in wood expressed as a proportion of its oven-dry mass.

**1.5.2.8**

**Racking**

Effect caused by horizontal actions in the plane of a wall.

**1.5.2.9**

**Stiffness property**

A property used in the calculation of the deformation of the structure, such as modulus of elasticity, shear modulus, slip modulus.

**1.5.2.10**

**Slip modulus**

A property used in the calculation of the deformation between two members of a structure.

**1.6 Symbols used in EN 1995-1-1**

For the purpose of EN 1995-1-1, the following symbols apply.

*Latin upper case letters*

$A$	Cross-sectional area
$\boxed{A_1}$ $A_{ef}$	Effective area of the total contact surface between a punched metal plate fastener and the timber; Effective contact area in compression perpendicular to the grain $\boxed{A_1}$
$A_f$	Cross-sectional area of flange
$A_{net,t}$	Net cross-sectional area perpendicular to the grain
$A_{net,v}$	Net shear area parallel to the grain
$C$	Spring stiffness
$E_{0,05}$	Fifth percentile value of modulus of elasticity;
$E_d$	Design value of modulus of elasticity;
$E_{mean}$	Mean value of modulus of elasticity;
$E_{mean,fin}$	Final mean value of modulus of elasticity;
$F$	Force
$F_{A,Ed}$	Design force acting on a punched metal plate fastener at the centroid of the effective area
$F_{A,min,d}$	Minimum design force acting on a punched metal plate fastener at the centroid of the effective area
$F_{ax,Ed}$	Design axial force on fastener;
$F_{ax,Rd}$	Design value of axial withdrawal capacity of the fastener;
$F_{ax,Rk}$	Characteristic axial withdrawal capacity of the fastener;
$F_c$	Compressive force

$F_d$	Design force
$F_{d,ser}$	Design force at the serviceability limit state
$F_{t,Rd}$	Design load-carrying capacity per fastener in wall diaphragm
$F_{i,c,Ed}$	Design compressive reaction force at end of shear wall
$F_{i,t,Ed}$	Design tensile reaction force at end of shear wall
$F_{i,vert,Ed}$	Vertical load on wall
$F_{i,v,Rd}$	Design racking resistance of panel $i$ (in 9.2.4.2) or wall $i$ (in 9.2.4.3)
$F_{la}$	Lateral load
$F_{M,Ed}$	Design force from a design moment
$F_t$	Tensile force
$F_{t,Rk}$	Characteristic tensile resistance of connection $A_1$
$F_{v,0,Rk}$	Characteristic load-carrying capacity of a connector along the grain;
$F_{v,Ed}$	Design shear force per shear plane of fastener; Horizontal design effect on wall diaphragm
$F_{v,Rd}$	Design load-carrying capacity per shear plane per fastener; Design racking load capacity
$F_{v,Rk}$	Characteristic load-carrying capacity per shear plane per fastener
$F_{v,w,Ed}$	Design shear force acting on web;
$F_{x,Ed}$	Design value of a force in x-direction
$F_{y,Ed}$	Design value of a force in y-direction
$F_{x,Rd}$	Design value of plate capacity in x-direction;
$F_{y,Rd}$	Design value of plate capacity in y-direction;
$F_{x,Rk}$	Characteristic plate capacity in x-direction;
$F_{y,Rk}$	Characteristic plate capacity in y-direction;
$G_{0,05}$	Fifth percentile value of shear modulus
$G_d$	Design value of shear modulus
$G_{mean}$	Mean value of shear modulus
$H$	Overall rise of a truss
$I_f$	Second moment of area of flange
$I_{tor}$	Torsional moment of inertia
$I_z$	Second moment of area about the weak axis
$K_{ser}$	Slip modulus
$K_{ser,fin}$	Final slip modulus
$K_u$	Instantaneous slip modulus for ultimate limit states
$L_{net,t}$	Net width of the cross-section perpendicular to the grain
$L_{net,v}$	Net length of the fracture area in shear
$M_{A,Ed}$	Design moment acting on a punched metal plate fastener
$M_{ap,d}$	Design moment at apex zone
$M_d$	Design moment
$M_{y,Rk}$	Characteristic yield moment of fastener
$N$	Axial force
$R_{90,d}$	Design splitting capacity
$R_{90,k}$	Characteristic splitting capacity
$R_{ax,d}$	Design load-carrying capacity of an axially loaded connection
$R_{ax,k}$	Characteristic load-carrying capacity of an axially loaded connection
$R_{ax,\alpha,k}$	Characteristic load-carrying capacity at an angle to grain
$R_d$	Design value of a load-carrying capacity
$R_{ef,k}$	Effective characteristic load-carrying capacity of a connection
$R_{iv,d}$	Design racking racking capacity of a wall
$R_k$	Characteristic load-carrying capacity
$R_{sp,k}$	Characteristic splitting capacity
$R_{to,k}$	Characteristic load-carrying capacity of a toothed plate connector
$R_{v,d}$	Design racking capacity of a wall diaphragm
$V$	Shear force; Volume
$V_u, V_l$	Shear forces in upper and lower part of beam with a hole
$W_y$	Section modulus about axis $y$
$X_d$	Design value of a strength property
$X_k$	Characteristic value of a strength property

*Latin lower case letters*

$a$	Distance
$a_1$	Spacing, parallel to grain, of fasteners within one row
$\overline{A_1} a_{1,CG}$	End distance of centre of gravity of the threaded part of screw in the member $\overline{A_1}$
$a_2$	Spacing, perpendicular to grain, between rows of fasteners
$\overline{A_1} a_{2,CG}$	Edge distance of centre of gravity of the threaded part of screw in the member $\overline{A_1}$
$a_{3,c}$	Distance between fastener and unloaded end
$a_{3,t}$	Distance between fastener and loaded end
$a_{4,c}$	Distance between fastener and unloaded edge
$a_{4,t}$	Distance between fastener and loaded edge
$a_{bow}$	Maximum bow of truss member
$a_{bow,perm}$	Maximum permitted bow of truss member
$a_{dev}$	Maximum deviation of truss
$a_{dev,perm}$	Maximum permitted deviation of truss
$b$	Width
$b_i$	Width of panel $i$ (in 9.2.4.2) or wall $i$ (in 9.2.4.3)
$b_{net}$	Clear distance between studs
$b_w$	Web width
$\overline{A_1} d$	Diameter; Outer thread diameter
$d_1$	Inner thread diameter $\overline{A_1}$
$d_c$	Connector diameter
$d_{ef}$	Effective diameter
$\overline{A_1} d_h$	Head diameter of screws $\overline{A_1}$
$f_{h,i,k}$	Characteristic embedment strength of timber member $i$
$f_{a,0,0}$	Characteristic anchorage capacity per unit area for $\alpha = 0^\circ$ and $\beta = 0^\circ$
$f_{a,90,90}$	Characteristic anchorage capacity per unit area for $\alpha = 90^\circ$ and $\beta = 90^\circ$
$f_{a,\alpha,\beta,k}$	Characteristic anchorage strength
$\overline{A_1} f_{ax,k}$	Characteristic pointside withdrawal strength for nails; Characteristic withdrawal strength $\overline{A_1}$
$f_{c,0,d}$	Design compressive strength along the grain
$f_{c,w,d}$	Design compressive strength of web
$f_{f,c,d}$	Design compressive strength of flange
$f_{c,90,k}$	Characteristic compressive strength perpendicular to grain
$f_{f,t,d}$	Design tensile strength of flange
$f_{h,k}$	Characteristic embedment strength
$f_{head,k}$	Characteristic pull through parameter for nails
$f_1$	Fundamental frequency
$f_{m,k}$	Characteristic bending strength
$f_{m,y,d}$	Design bending strength about the principal y-axis
$f_{m,z,d}$	Design bending strength about the principal z-axis
$f_{m,\alpha,d}$	Design bending strength at an angle $\alpha$ to the grain
$f_{t,0,d}$	Design tensile strength along the grain
$f_{t,0,k}$	Characteristic tensile strength along the grain
$f_{t,90,d}$	Design tensile strength perpendicular to the grain
$f_{t,w,d}$	Design tensile strength of the web
$f_{u,k}$	Characteristic tensile strength of bolts
$f_{v,0,d}$	Design panel shear strength
$f_{v,ax,\alpha,k}$	Characteristic withdrawal strength at an angle to grain
$f_{v,ax,90,k}$	Characteristic withdrawal strength perpendicular to grain
$f_{v,d}$	Design shear strength
$h$	Depth; Height of wall
$h_{ap}$	Depth of the apex zone
$h_d$	Hole depth
$h_e$	Embedment depth
$h$	Loaded edge distance
$h_{ef}$	Effective depth
$h_{f,c}$	Depth of compression flange

$h_{f,t}$	Depth of tension flange
$h_{rl}$	Distance from lower edge of hole to bottom of member
$h_{ru}$	Distance from upper edge of hole to top of member
$h_w$	Web depth
$i$	Notch inclination
$k_{c,y}$ or $k_{c,z}$	Instability factor
$\sqrt{A_1}$ $k_{cr}$	Crack factor for shear resistance $\sqrt{A_1}$
$k_{crit}$	Factor used for lateral buckling
$k_d$	Dimension factor for panel
$k_{def}$	Deformation factor
$k_{dis}$	Factor taking into account the distribution of stresses in an apex zone
$k_{f,1}, k_{f,2}, k_{f,3}$	Modification factors for bracing resistance
$k_h$	Depth factor
$k_{i,q}$	Uniformly distributed load factor
$k_m$	Factor considering re-distribution of bending stresses in a cross-section
$k_{mod}$	Modification factor for duration of load and moisture content
$k_n$	Sheathing material factor
$k_r$	Reduction factor
$k_{R,red}$	Reduction factor for load-carrying capacity
$k_s$	Fastener spacing factor; Modification factor for spring stiffness
$k_{s,red}$	Reduction factor for spacing
$k_{shape}$	Factor depending on the shape of the cross-section
$k_{sys}$	System strength factor
$k_v$	Reduction factor for notched beams
$k_{vol}$	Volume factor
$k_y$ or $k_z$	Instability factor
$\ell_{a,min}$	Minimum anchorage length for a glued-in rod
$\ell$	Span; contact length
$\ell_A$	Support distance of a hole
$\ell_{ef}$	Effective length; Effective length of distribution
$\ell_V$	Distance from a hole to the end of the member
$\ell_Z$	Spacing between holes
$m$	Mass per unit area
$n_{40}$	Number of frequencies below 40 Hz
$n_{ef}$	Effective number of fasteners
$p_d$	Distributed load
$q_i$	Equivalent uniformly distributed load
$r$	Radius of curvature
$s$	Spacing
$s_0$	Basic fastener spacing
$r_{in}$	Inner radius
$t$	Thickness
$t_{pen}$	Penetration depth
$u_{creep}$	Creep deformation
$u_{fin}$	Final deformation
$u_{fin,G}$	Final deformation for a permanent action $G$
$u_{fin,Q,1}$	Final deformation for the leading variable action $Q_1$
$u_{fin,Q,i}$	Final deformation for accompanying variable actions $Q_i$
$u_{inst}$	Instantaneous deformation
$u_{inst,G}$	Instantaneous deformation for a permanent action $G$
$u_{inst,Q,1}$	Instantaneous deformation for the leading variable action $Q_1$
$u_{inst,Q,i}$	Instantaneous deformation for accompanying variable actions $Q_i$
$w_c$	Precamber
$w_{creep}$	Creep deflection
$w_{fin}$	Final deflection
$w_{inst}$	Instantaneous deflection
$w_{net,fin}$	Net final deflection
$v$	Unit impulse velocity response

*Greek lower case letters*

$\alpha$	Angle between the x-direction and the force for a punched metal plate; Angle between a force and the direction of grain; Angle between the direction of the load and the loaded edge (or end)
$\beta$	Angle between the grain direction and the force for a punched metal plate
$\beta_c$	Straightness factor
$\gamma$	Angle between the x-direction and the timber connection line for a punched metal plate
$\gamma_M$	Partial factor for material properties, also accounting for model uncertainties and dimensional variations
$\lambda_y$	Slenderness ratio corresponding to bending about the y-axis
$\lambda_z$	Slenderness ratio corresponding to bending about the z-axis
$\lambda_{rel,y}$	Relative slenderness ratio corresponding to bending about the y-axis
$\lambda_{rel,z}$	Relative slenderness ratio corresponding to bending about the z-axis
$\overline{\rho_a}$	Associated density $\overline{\rho_a}$
$\rho_k$	Characteristic density
$\rho_m$	Mean density
$\sigma_{c,0,d}$	Design compressive stress along the grain
$\sigma_{c,\alpha,d}$	Design compressive stress at an angle $\alpha$ to the grain
$\sigma_{f,c,d}$	Mean design compressive stress of flange
$\sigma_{f,c,max,d}$	Design compressive stress of extreme fibres of flange
$\sigma_{f,t,d}$	Mean design tensile stress of flange
$\sigma_{f,t,max,d}$	Design tensile stress of extreme fibres of flange
$\sigma_{m,crit}$	Critical bending stress
$\sigma_{m,y,d}$	Design bending stress about the principal y-axis
$\sigma_{m,z,d}$	Design bending stress about the principal z-axis
$\sigma_{m,\alpha,d}$	Design bending stress at an angle $\alpha$ to the grain
$\sigma_N$	Axial stress
$\sigma_{t,0,d}$	Design tensile stress along the grain
$\sigma_{t,90,d}$	Design tensile stress perpendicular to the grain
$\sigma_{w,c,d}$	Design compressive stress of web
$\sigma_{w,t,d}$	Design tensile stress of web
$\tau_d$	Design shear stress
$\tau_{F,d}$	Design anchorage stress from axial force
$\tau_{M,d}$	Design anchorage stress from moment
$\tau_{tor,d}$	Design shear stress from torsion
$\psi_0$	Factor for combination value of a variable action
$\psi_2$	Factor for quasi-permanent value of a variable action
$\zeta$	Modal damping ratio

## Section 2 Basis of design

### 2.1 Requirements

#### 2.1.1 Basic requirements

(1)P The design of timber structures shall be in accordance with EN 1990:2002.

(2)P The supplementary provisions for timber structures given in this section shall also be applied.

(3) The basic requirements of EN 1990:2002 section 2 are deemed to be satisfied for timber structures when limit state design, in conjunction with the partial factor method using EN 1990:2002 and EN 1991 for actions and their combinations and EN 1995 for resistances, rules for serviceability and durability, is applied.

#### 2.1.2 Reliability management

(1) When different levels of reliability are required, these levels should be preferably achieved by an appropriate choice of quality management in design and execution, according to EN 1990:2002 Annex C.

#### 2.1.3 Design working life and durability

$\text{A}_1$  (1) EN 1990:2002 clauses 2.3 and 2.4 apply.  $\text{A}_1$

### 2.2 Principles of limit state design

#### 2.2.1 General

(1)P The design models for the different limit states shall, as appropriate, take into account the following:

- different material properties (e.g. strength and stiffness);
- different time-dependent behaviour of the materials (duration of load, creep);
- different climatic conditions (temperature, moisture variations);
- different design situations (stages of construction, change of support conditions).

#### 2.2.2 Ultimate limit states

(1)P The analysis of structures shall be carried out using the following values for stiffness properties:

- for a first order linear elastic analysis of a structure, whose distribution of internal forces is not affected by the stiffness distribution within the structure (eg. all members have the same time-dependent properties), mean values shall be used;
- for a first order linear elastic analysis of a structure, whose distribution of internal forces is affected by the stiffness distribution within the structure (eg. composite members containing materials having different time-dependent properties), final mean values adjusted to the load component causing the largest stress in relation to strength shall be used;
- for a second order linear elastic analysis of a structure, design values, not adjusted for duration of load, shall be used.

NOTE 1: For final mean values adjusted to the duration of load, see 2.3.2.2(2).

NOTE 2: For design values of stiffness properties, see 2.4.1(2)P.

(2) The slip modulus of a connection for the ultimate limit state,  $K_u$ , should be taken as:

$$K_u = \frac{2}{3} K_{ser} \quad (2.1)$$

Ⓐ where  $K_{ser}$  is the slip modulus, see 7.1(1). Ⓐ

### 2.2.3 Serviceability limit states

(1)P The deformation of a structure which results from the effects of actions (such as axial and shear forces, bending moments and joint slip) and from moisture shall remain within appropriate limits, having regard to the possibility of damage to surfacing materials, ceilings, floors, partitions and finishes, and to the functional needs as well as any appearance requirements.

(2) The instantaneous deformation,  $u_{inst}$ , see figure 7.1, should be calculated for the characteristic combination of actions, see EN 1990, clause 6.5.3(2) a), using mean values of the appropriate moduli of elasticity, shear moduli and slip moduli.

(3) The final deformation,  $u_{fin}$ , see figure 7.1, should be calculated for the quasi-permanent combination of actions, see EN 1990, clause 6.5.3(2) c).

(4) If the structure consists of members or components having different creep behaviour, the final deformation should be calculated using final mean values of the appropriate moduli of elasticity, shear moduli and slip moduli, according to 2.3.2.2(1).

(5) For structures consisting of members, components and connections with the same creep behaviour and under the assumption of a linear relationship between the actions and the corresponding deformations, as a simplification of 2.2.3(3), the final deformation,  $u_{fin}$ , may be taken as:

$$\text{Ⓐ} u_{fin} = u_{fin,G} + u_{fin,Q_1} + \sum u_{fin,Q_i} \quad \text{Ⓐ} \quad (2.2)$$

where:

$$u_{fin,G} = u_{inst,G} (1 + k_{def}) \quad \text{for a permanent action, } G \quad (2.3)$$

$$u_{fin,Q_1} = u_{inst,Q_1} (1 + \psi_{2,1} k_{def}) \quad \text{for the leading variable action, } Q_1 \quad (2.4)$$

$$u_{fin,Q_i} = u_{inst,Q_i} (\psi_{0,i} + \psi_{2,i} k_{def}) \quad \text{for accompanying variable actions, } Q_i \ (i > 1) \quad (2.5)$$

$u_{inst,G}$ ,  $u_{inst,Q_1}$ ,  $u_{inst,Q_i}$  are the instantaneous deformations for action  $G$ ,  $Q_1$ ,  $Q_i$  respectively;

$\psi_{2,1}$ ,  $\psi_{2,i}$  are the factors for the quasi-permanent value of variable actions;

$\psi_{0,i}$  are the factors for the combination value of variable actions;

$k_{def}$  is given in table 3.2 for timber and wood-based materials, and in 2.3.2.2 (3) and 2.3.2.2 (4) for connections.

When expressions (2.3) to (2.5) are used, the  $\psi_2$  factors should be omitted from expressions (6.16a) and (6.16b) of EN1990:2002.

Note: In most cases, it will be appropriate to apply the simplified method.

(6) For serviceability limit states with respect to vibrations, mean values of the appropriate stiffness moduli should be used.

## 2.3 Basic variables

### 2.3.1 Actions and environmental influences

#### 2.3.1.1 General

(1) Actions to be used in design may be obtained from the relevant parts of EN 1991.

Note 1: The relevant parts of EN 1991 for use in design include:

EN 1991-1-1	Densities, self-weight and imposed loads
EN 1991-1-3	Snow loads
EN 1991-1-4	Wind actions
EN 1991-1-5	Thermal actions
EN 1991-1-6	Actions during execution
EN 1991-1-7	Accidental actions

(2)P Duration of load and moisture content affect the strength and stiffness properties of timber and wood-based elements and shall be taken into account in the design for mechanical resistance and serviceability.

(3)P Actions caused by the effects of moisture content changes in the timber shall be taken into account.

#### 2.3.1.2 Load-duration classes

(1)P The load-duration classes are characterised by the effect of a constant load acting for a certain period of time in the life of the structure. For a variable action the appropriate class shall be determined on the basis of an estimate of the typical variation of the load with time.

(2)P Actions shall be assigned to one of the load-duration classes given in Table 2.1 for strength and stiffness calculations.

**Table 2.1 – Load-duration classes**

Load-duration class	Order of accumulated duration of characteristic load
Permanent	more than 10 years
Long-term	6 months – 10 years
Medium-term	1 week – 6 months
Short-term	less than one week
Instantaneous	

NOTE: Examples of load-duration assignment are given in Table 2.2. Since climatic loads (snow, wind) vary between countries, the assignment of load-duration classes may be specified in the National annex.

**Table 2.2 – Examples of load-duration assignment**

Load-duration class	Examples of loading
Permanent	self-weight
Long-term	storage
Medium-term	imposed floor load, snow
Short-term	snow, wind
Instantaneous	wind, accidental load

### 2.3.1.3 Service classes

(1)P Structures shall be assigned to one of the service classes given below:

NOTE 1: The service class system is mainly aimed at assigning strength values and for calculating deformations under defined environmental conditions.

NOTE 2: Information on the assignment of structures to service classes given in (2)P, (3)P and (4)P may be given in the National annex.

(2)P Service class 1 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 65 % for a few weeks per year.

NOTE: In service class 1 the average moisture content in most softwoods will not exceed 12 %.

(3)P Service class 2 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 85 % for a few weeks per year.

NOTE: In service class 2 the average moisture content in most softwoods will not exceed 20 %.

(4)P Service class 3 is characterised by climatic conditions leading to higher moisture contents than in service class 2.

## 2.3.2 Materials and product properties

### 2.3.2.1 Load-duration and moisture influences on strength

(1) Modification factors for the influence of load-duration and moisture content on strength, see 2.4.1, are given in 3.1.3.

(2) Where a connection is constituted of two timber elements having different time-dependent behaviour, the calculation of the design load-carrying capacity should be made with the following modification factor  $k_{\text{mod}}$ :

$$k_{\text{mod}} = \sqrt{k_{\text{mod},1} k_{\text{mod},2}} \quad (2.6)$$

where  $k_{\text{mod},1}$  and  $k_{\text{mod},2}$  are the modification factors for the two timber elements.

### 2.3.2.2 Load-duration and moisture influences on deformations

(1) For serviceability limit states, if the structure consists of members or components having different time-dependent properties, the final mean value of modulus of elasticity,  $E_{\text{mean,fin}}$ , shear modulus  $G_{\text{mean,fin}}$ , and slip modulus,  $K_{\text{ser,fin}}$ , which are used to calculate the final deformation should be taken from the following expressions:

$$E_{\text{mean,fin}} = \frac{E_{\text{mean}}}{(1 + k_{\text{def}})} \quad (2.7)$$

$$G_{\text{mean,fin}} = \frac{G_{\text{mean}}}{(1 + k_{\text{def}})} \quad (2.8)$$

$$K_{\text{ser,fin}} = \frac{K_{\text{ser}}}{(1 + k_{\text{def}})} \quad (2.9)$$

(2) For ultimate limit states, where the distribution of member forces and moments is affected by the stiffness distribution in the structure, the final mean value of modulus of elasticity,  $E_{\text{mean,fin}}$ , shear modulus  $G_{\text{mean,fin}}$ , and slip modulus,  $K_{\text{ser,fin}}$ , should be calculated from the following expressions :

$$E_{\text{mean,fin}} = \frac{E_{\text{mean}}}{(1 + \psi_2 k_{\text{def}})} \quad (2.10)$$

$$G_{\text{mean,fin}} = \frac{G_{\text{mean}}}{(1 + \psi_2 k_{\text{def}})} \quad (2.11)$$

$$K_{\text{ser,fin}} = \frac{K_{\text{ser}}}{(1 + \psi_2 k_{\text{def}})} \quad (2.12)$$

where:

$E_{\text{mean}}$  is the mean value of modulus of elasticity;

$G_{\text{mean}}$  is the mean value of shear modulus;

$K_{\text{ser}}$  is the slip modulus;

$k_{\text{def}}$  is a factor for the evaluation of creep deformation taking into account the relevant service class;

$\psi_2$  is the factor for the quasi-permanent value of the action causing the largest stress in relation to the strength (if this action is a permanent action,  $\psi_2$  should be replaced by 1).

NOTE 1: Values of  $k_{\text{def}}$  are given in 3.1.4.

NOTE 2: Values of  $\psi_2$  are given in EN 1990:2002.

(3) Where a connection is constituted of timber elements with the same time-dependent behaviour, the value of  $k_{\text{def}}$  should be doubled.

(4) Where a connection is constituted of two wood-based elements having different time-dependent behaviour, the calculation of the final deformation should be made with the following deformation factor  $k_{\text{def}}$ :

$$k_{\text{def}} = 2 \sqrt{k_{\text{def},1} k_{\text{def},2}} \quad (2.13)$$

where  $k_{\text{def},1}$  and  $k_{\text{def},2}$  are the deformation factors for the two timber elements.

## 2.4 Verification by the partial factor method

### 2.4.1 Design value of material property

(1)P The design value  $X_d$  of a strength property shall be calculated as:

$$X_d = k_{\text{mod}} \frac{X_k}{\gamma_M} \quad (2.14)$$

where:

$X_k$  is the characteristic value of a strength property;

$\gamma_M$  is the partial factor for a material property;

$k_{\text{mod}}$  is a modification factor taking into account the effect of the duration of load and moisture content.

NOTE 1: Values of  $k_{\text{mod}}$  are given in 3.1.3.

NOTE 2: The recommended partial factors for material properties ( $\gamma_M$ ) are given in Table 2.3. Information on the National choice may be found in the National annex.

**Table 2.3 – Recommended partial factors  $\gamma_M$  for material properties and resistances**

Fundamental combinations:	
Solid timber	1,3
Glued laminated timber	1,25
LVL, plywood, OSB, Particleboards	1,2
Fibreboards, hard	1,3
Fibreboards, medium	1,3
Fibreboards, MDF	1,3
Fibreboards, soft	1,3
Connections	1,3
Punched metal plate fasteners	1,25
Accidental combinations	1,0

(2)P The design member stiffness property  $E_d$  or  $G_d$  shall be calculated as:

$$E_d = \frac{E_{\text{mean}}}{\gamma_M} \quad (2.15)$$

$$G_d = \frac{G_{\text{mean}}}{\gamma_M} \quad (2.16)$$

where:

$E_{\text{mean}}$  is the mean value of modulus of elasticity;

$G_{\text{mean}}$  is the mean value of shear modulus.

#### 2.4.2 Design value of geometrical data

- (1) Geometrical data for cross-sections and systems may be taken as nominal values from product standards hEN or drawings for the execution.
- (2) Design values of geometrical imperfections specified in this standard comprise the effects of
- geometrical imperfections of members;
  - the effects of structural imperfections from fabrication and erection;
  - inhomogeneity of materials (e.g. due to knots).

#### 2.4.3 Design resistances

- (1)P The design value  $R_d$  of a resistance (load-carrying capacity) shall be calculated as:

$$R_d = k_{\text{mod}} \frac{R_k}{\gamma_M} \quad (2.17)$$

where:

$R_k$  is the characteristic value of load-carrying capacity;

$\gamma_M$  is the partial factor for a material property,

$k_{\text{mod}}$  is a modification factor taking into account the effect of the duration of load and moisture content.

NOTE 1: Values of  $k_{\text{mod}}$  are given in 3.1.3.

NOTE 2: For partial factors, see 2.4.1.

#### 2.4.4 Verification of equilibrium (EQU)

- (1) The reliability format for the verification of static equilibrium given in Table A1.2 (A) in Annex A1 of EN 1990:2002 applies, where appropriate, to the design of timber structures, e.g. for the design of holding-down anchors or the verification of bearings subject to uplift from continuous beams.

## Section 3 Material properties

### 3.1 General

#### 3.1.1 Strength and stiffness parameters

(1)P Strength and stiffness parameters shall be determined on the basis of tests for the types of action effects to which the material will be subjected in the structure, or on the basis of comparisons with similar timber species and grades or wood-based materials, or on well-established relations between the different properties.

#### 3.1.2 Stress-strain relations

(1)P Since the characteristic values are determined on the assumption of a linear relation between stress and strain until failure, the strength verification of individual members shall also be based on such a linear relation.

(2) For members or parts of members subjected to compression, a non-linear relationship (elastic-plastic) may be used.

#### 3.1.3 Strength modification factors for service classes and load-duration classes

(1) The values of the modification factor  $k_{\text{mod}}$  given in Table 3.1 should be used.

(2) If a load combination consists of actions belonging to different load-duration classes a value of  $k_{\text{mod}}$  should be chosen which corresponds to the action with the shortest duration, e.g. for a combination of dead load and a short-term load, a value of  $k_{\text{mod}}$  corresponding to the short-term load should be used.

#### 3.1.4 Deformation modification factors for service classes

(1) The values of the deformation factors  $k_{\text{def}}$  given in Table 3.2 should be used.

### 3.2 Solid timber

**A1** (1)P Timber members shall comply with EN 14081-1.

NOTE: Strength classes for timber are given in EN 338. **A1**

(2) The effect of member size on strength may be taken into account.

(3) For rectangular solid timber with a characteristic timber density  $\rho_k \leq 700 \text{ kg/m}^3$ , the reference depth in bending or width (maximum cross-sectional dimension) in tension is 150 mm. For depths in bending or widths in tension of solid timber less than 150 mm the characteristic values for  $f_{\text{m,k}}$  and  $f_{\text{t,0,k}}$  may be increased by the factor  $k_{\text{h}}$ , given by:

$$k_{\text{h}} = \min \left\{ \begin{array}{l} \left( \frac{150}{h} \right)^{0,2} \\ 1,3 \end{array} \right. \quad (3.1)$$

where  $h$  is the depth for bending members or width for tension members, in mm.

**A1** Table 3.1 – Values of  $k_{mod}$

Material	Standard	Service class	Load-duration class				
			Permanent action	Long term action	Medium term action	Short term action	Instantaneous action
Solid timber	EN 14081-1	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
Glued laminated timber	EN 14080	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
LVL	EN 14374, EN 14279	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
Plywood	EN 636 Type EN 636-1 Type EN 636-2 Type EN 636-3	1	0,60	0,70	0,80	0,90	1,10
		2	0,60	0,70	0,80	0,90	1,10
		3	0,50	0,55	0,65	0,70	0,90
OSB	EN 300 OSB/2 OSB/3, OSB/4 OSB/3, OSB/4	1	0,30	0,45	0,65	0,85	1,10
		1	0,40	0,50	0,70	0,90	1,10
		2	0,30	0,40	0,55	0,70	0,90
Particle-board	EN 312 Type P4, Type P5 Type P5 Type P6, Type P7 Type P7	1	0,30	0,45	0,65	0,85	1,10
		2	0,20	0,30	0,45	0,60	0,80
		1	0,40	0,50	0,70	0,90	1,10
		2	0,30	0,40	0,55	0,70	0,90
Fibreboard, hard	EN 622-2 HB.LA, HB.HLA 1 or 2 HB.HLA1 or 2	1	0,30	0,45	0,65	0,85	1,10
		2	0,20	0,30	0,45	0,60	0,80
Fibreboard, medium	EN 622-3 MBH.LA1 or 2 MBH.HLS1 or 2 MBH.HLS1 or 2	1	0,20	0,40	0,60	0,80	1,10
		1	0,20	0,40	0,60	0,80	1,10
		2	–	–	–	0,45	0,80
Fibreboard, MDF	EN 622-5 MDF.LA, MDF.HLS MDF.HLS	1	0,20	0,40	0,60	0,80	1,10
		2	–	–	–	0,45	0,80

(4) For timber which is installed at or near its fibre saturation point, and which is likely to dry out under load, the values of  $k_{def}$ , given in Table 3.2, should be increased by 1,0.

(5)P Finger joints shall comply with EN 385.

### 3.3 Glued laminated timber

(1)P Glued laminated timber members shall comply with EN 14080.

NOTE: In EN 1194 values of strength and stiffness properties are given for glued laminated timber allocated to strength classes, see annex D (Informative).

(2) The effect of member size on strength may be taken into account.

(3) For rectangular glued laminated timber, the reference depth in bending or width in tension is 600 mm. For depths in bending or widths in tension of glued laminated timber less than 600 mm

the characteristic values for  $f_{m,k}$  and  $f_{t,0,k}$  may be increased by the factor  $k_h$ , given by

$$k_h = \min \left\{ \begin{array}{l} \left( \frac{600}{h} \right)^{0,1} \\ 1,1 \end{array} \right. \quad (3.2)$$

where  $h$  is the depth for bending members or width for tensile members, in mm.

**A1**) (4)P Large finger joints complying with the requirements of EN 387 shall not be used for products to be installed in service class 3, where the direction of grain changes at the joint. **A1**)

(5)P The effect of member size on the tensile strength perpendicular to the grain shall be taken into account.

**A1**) Table 3.2 – Values of  $k_{def}$  for timber and wood-based materials

Material	Standard	Service class		
		1	2	3
Solid timber	EN 14081-1	0,60	0,80	2,00
Glued Laminated timber	EN 14080	0,60	0,80	2,00
LVL	EN 14374, EN 14279	0,60	0,80	2,00
Plywood	EN 636			
	Type EN 636-1	0,80	–	–
	Type EN 636-2	0,80	1,00	–
	Type EN 636-3	0,80	1,00	2,50
OSB	EN 300			
	OSB/2	2,25	–	–
	OSB/3, OSB/4	1,50	2,25	–
Particleboard	EN 312			
	Type P4	2,25	–	–
	Type P5	2,25	3,00	–
	Type P6	1,50	–	–
	Type P7	1,50	2,25	–
Fibreboard, hard	EN 622-2			
	HB.LA HB.HLA1, HB.HLA2	2,25 2,25	– 3,00	– –
Fibreboard, medium	EN 622-3			
	MBH.LA1, MBH.LA2 MBH.HLS1, MBH.HLS2	3,00 3,00	– 4,00	– –
Fibreboard, MDF	EN 622-5			
	MDF.LA MDF.HLS	2,25 2,25	– 3,00	– –

**A1**)

### 3.4 Laminated veneer lumber (LVL)

(1)P LVL structural members shall comply with EN 14374.

(2)P For rectangular LVL with the grain of all veneers running essentially in one direction, the effect of member size on bending and tensile strength shall be taken into account.

(3) The reference depth in bending is 300 mm. For depths in bending not equal to 300 mm the characteristic value for  $f_{m,k}$  should be multiplied by the factor  $k_h$ , given by

$$k_h = \min \left\{ \begin{array}{l} \left( \frac{300}{h} \right)^s \\ 1,2 \end{array} \right. \quad (3.3)$$

where:

$h$  is the depth of the member, in mm;

$s$  is the size effect exponent, refer to 3.4(5)P.

(4) The reference length in tension is 3000 mm. For lengths in tension not equal to 3000 mm the characteristic value for  $f_{t,0,k}$  should be multiplied by the factor  $k_\ell$  given by

$$k_\ell = \min \left\{ \begin{array}{l} \left( \frac{3000}{\ell} \right)^{s/2} \\ 1,1 \end{array} \right. \quad (3.4)$$

where  $\ell$  is the length, in mm.

(5)P The size effect exponent  $s$  for LVL shall be taken as declared in accordance with EN 14374.

**[A1]** (6)P Large finger joints complying with the requirements of EN 387 shall not be used for products to be installed in service class 3, where the direction of grain changes at the joint. **[A1]**

(7)P For LVL with the grain of all veneers running essentially in one direction, the effect of member size on the tensile strength perpendicular to the grain shall be taken into account.

### 3.5 Wood-based panels

(1)P Wood-based panels shall comply with EN 13986 and LVL used as panels shall comply with EN 14279.

(2) The use of softboards according to EN 622-4 should be restricted to wind bracing and should be designed by testing.

### 3.6 Adhesives

(1)P Adhesives for structural purposes shall produce joints of such strength and durability that the integrity of the bond is maintained in the assigned service class throughout the expected life of the structure.

(2) Adhesives which comply with Type I specification as defined in EN 301 may be used in all service classes.

(3) Adhesives which comply with Type II specification as defined in EN 301 should only be used in service classes 1 or 2 and not under prolonged exposure to temperatures in excess of 50°C.

### 3.7 Metal fasteners

(1)P Metal fasteners shall comply with EN 14592 and metal connectors shall comply with EN 14545.

## Section 4 Durability

### 4.1 Resistance to biological organisms

(1)P Timber and wood-based materials shall either have adequate natural durability in accordance with EN 350-2 for the particular hazard class (defined in EN 335-1, EN 335-2 and EN 335-3), or be given a preservative treatment selected in accordance with EN 351-1 and EN 460.

NOTE 1: Preservative treatment may affect the strength and stiffness properties.

NOTE 2: Rules for specification of preservation treatments are given in EN 350-2 and EN 335.

### 4.2 Resistance to corrosion

(1)P Metal fasteners and other structural connections shall, where necessary, either be inherently corrosion-resistant or be protected against corrosion.

(2) Examples of minimum corrosion protection or material specifications for different service classes (see 2.3.1.3) are given in Table 4.1.

**Table 4.1 – Examples of minimum specifications for material protection against corrosion for fasteners (related to ISO 2081)**

Fastener	Service Class <sup>b</sup>		
	1	2	3
Nails and screws with $d \leq 4$ mm	None	Fe/Zn 12c <sup>a</sup>	Fe/Zn 25c <sup>a</sup>
Bolts, dowels, nails and screws with $d > 4$ mm	None	None	Fe/Zn 25c <sup>a</sup>
Staples	Fe/Zn 12c <sup>a</sup>	Fe/Zn 12c <sup>a</sup>	Stainless steel
Punched metal plate fasteners and steel plates up to 3 mm thickness	Fe/Zn 12c <sup>a</sup>	Fe/Zn 12c <sup>a</sup>	Stainless steel
Steel plates from 3 mm up to 5 mm in thickness	None	Fe/Zn 12c <sup>a</sup>	Fe/Zn 25c <sup>a</sup>
Steel plates over 5 mm thickness	None	None	Fe/Zn 25c <sup>a</sup>
<sup>a</sup> If hot dip zinc coating is used, Fe/Zn 12c should be replaced by Z275 and Fe/Zn 25c by Z350 in accordance with EN 10147			
<sup>b</sup> For especially corrosive conditions consideration should be given to heavier hot dip coatings or stainless steel.			

## Section 5 Basis of structural analysis

### 5.1 General

(1)P Calculations shall be performed using appropriate design models (supplemented, if necessary, by tests) involving all relevant variables. The models shall be sufficiently precise to predict the structural behaviour, commensurate with the standard of workmanship likely to be achieved, and with the reliability of the information on which the design is based.

(2) The global structural behaviour should be assessed by calculating the action effects with a linear material model (elastic behaviour).

(3) For structures able to redistribute the internal forces via connections of adequate ductility, elastic-plastic methods may be used for the calculation of the internal forces in the members.

(4)P The model for the calculation of internal forces in the structure or in part of it shall take into account the effects of deformations of the connections.

(5) In general, the influence of deformations in the connections should be taken into account through their stiffness (rotational or translational for instance) or through prescribed slip values as a function of the load level in the connection.

### 5.2 Members

(1)P The following shall be taken into account by the structural analysis:

- deviations from straightness;
- inhomogeneities of the material.

NOTE: Deviations from straightness and inhomogeneities are taken into account implicitly by the design methods given in this standard.

(2)P Reductions in the cross-sectional area shall be taken into account in the member strength verification.

(3) Reductions in the cross-sectional area may be ignored for the following cases:

- nails and screws with a diameter of 6 mm or less, driven without pre-drilling;
- holes in the compression area of members, if the holes are filled with a material of higher stiffness than the wood.

(4) When assessing the effective cross-section at a joint with multiple fasteners, all holes within a distance of half the minimum fastener spacing measured parallel to the grain from a given cross-section should be considered as occurring at that cross-section.

### 5.3 Connections

(1)P The load-carrying-capacity of the connections shall be verified taking into account the forces and the moments between the members determined by the global structural analysis.

(2)P The deformation of the connection shall be compatible with that assumed in the global analysis.

(3)P The analysis of a connection shall take into account the behaviour of all the elements which constitute the connection.

## 5.4 Assemblies

### 5.4.1 General

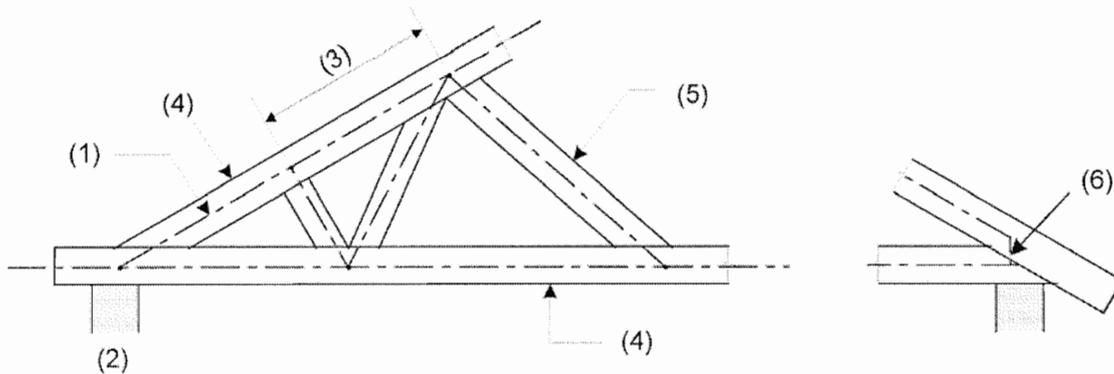
(1)P The analysis of structures shall be carried out using static models which consider to an acceptable level of accuracy the behaviour of the structure and of the supports.

(2) The analysis should be performed by frame models in accordance with 5.4.2 or by a simplified analysis in accordance with 5.4.3 for trusses with punched metal plate fasteners.

(3) Second order analysis of plane frames or arches should be performed in accordance with 5.4.4.

### 5.4.2 Frame structures

(1)P Frame structures shall be analysed such that the deformations of the members and joints, the influence of support eccentricities and the stiffness of the supporting structure are taken into account in the determination of the member forces and moments, see Figure 5.1 for definitions of structure configurations and model elements.



Key:

- (1) System line
- (2) Support
- (3) Bay
- (4) External member
- (5) Internal member
- (6) Fictitious beam element

**Figure 5.1 – Examples of frame analysis model elements**

(2)P In a frame analysis, the system lines for all members shall lie within the member profile. For the main members, e.g. the external members of a truss, the system lines shall coincide with the member centre-line.

(3)P If the system lines for internal members do not coincide with the centre lines, the influence of the eccentricity shall be taken into account in the strength verification of these members.

(4) Fictitious beam elements and spring elements may be used to model eccentric connections or supports. The orientation of fictitious beam elements and the location of the spring elements should coincide as closely as possible with the actual joint configuration.

(5) In a first order linear elastic analysis, the effect of initial deformations and induced deflections may be disregarded if taken into account by the strength verification of the member.

(6) The frame analysis should be carried out using the appropriate values of member stiffness defined in 2.2.2. Fictitious beam elements should be assumed to have a stiffness corresponding to that of the actual connections.

(7) Connections may be assumed to be rotationally stiff, if their deformation has no significant effect upon the distribution of member forces and moments. Otherwise, connections may be generally assumed to be rotationally pinned.

(8) Translational slip at the joints may be disregarded for the strength verification unless it significantly affects the distribution of internal forces and moments.

(9) Splice connections used in lattice structures may be modelled as rotationally stiff if the actual rotation under load would have no significant effect upon member forces. This requirement is fulfilled if one of the following conditions is satisfied:

- The splice connection has a load-carrying capacity which corresponds to at least 1,5 times the combination of applied force and moment
- The splice connection has a load-carrying capacity which corresponds to at least the combination of applied force and moment, provided that the timber members are not subject to bending stresses which are greater than 0,3 times the member bending strength, and the assembly would be stable if all such connections acted as pins.

#### 5.4.3 Simplified analysis of trusses with punched metal plate fasteners

(1) A simplified analysis of fully triangulated trusses should comply with the following conditions:

- there are no re-entrant angles in the external profile;
- the bearing width is situated within the length  $a_1$ , and the distance  $a_2$  in Figure 5.2 is not greater than  $a_1/3$  or 100 mm, whichever is the greater;
- the truss height is greater than 0,15 times the span and 10 times the maximum external member depth.

(2) The axial forces in the members should be determined on the basis that every node is pin-jointed.

(3) The bending moments in single-bay members should be determined on the basis that the end nodes are pin-jointed. Bending moments in members that are continuous over several bays should be determined on the basis that the member is a beam with a simple support at each node. The effect of deflection at the nodes and partial fixity at the connections should be taken into account by a reduction of 10 % of the moments at the inner supports of the member. The inner support moments should be used to calculate the span bending moments.

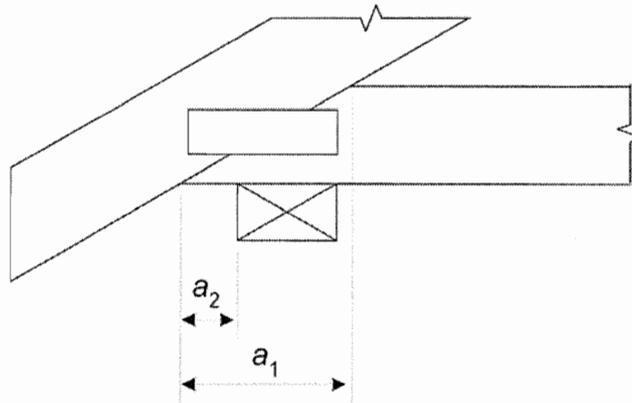


Figure 5.2 – Geometry of support

#### 5.4.4 Plane frames and arches

(1)P The requirements of 5.2 apply. The effects of induced deflection on internal forces and moments shall be taken into account.

(2) The effects of induced deflection on internal forces and moments may be taken into account by carrying out a second order linear analysis with the following assumptions:

- the imperfect shape of the structure should be assumed to correspond to an initial deformation which is found by applying an angle  $\phi$  of inclination to the structure or relevant parts, together with an initial sinusoidal curvature between the nodes of the structure corresponding to a maximum eccentricity  $e$ .
- the value of  $\phi$  in radians should as a minimum be taken as

$$\begin{aligned} \phi &= 0,005 && \text{for } h \leq 5 \text{ m} \\ \phi &= 0,005 \sqrt{5/h} && \text{for } h > 5 \text{ m} \end{aligned} \quad (5.1)$$

where  $h$  is the height of the structure or the length of the member, in m.

- the value of  $e$  should as a minimum be taken as:

$$e = 0,0025 \ell \quad (5.2)$$

Examples of assumed initial deviations in the geometry and the definition of  $\ell$  are given in Figure 5.3.

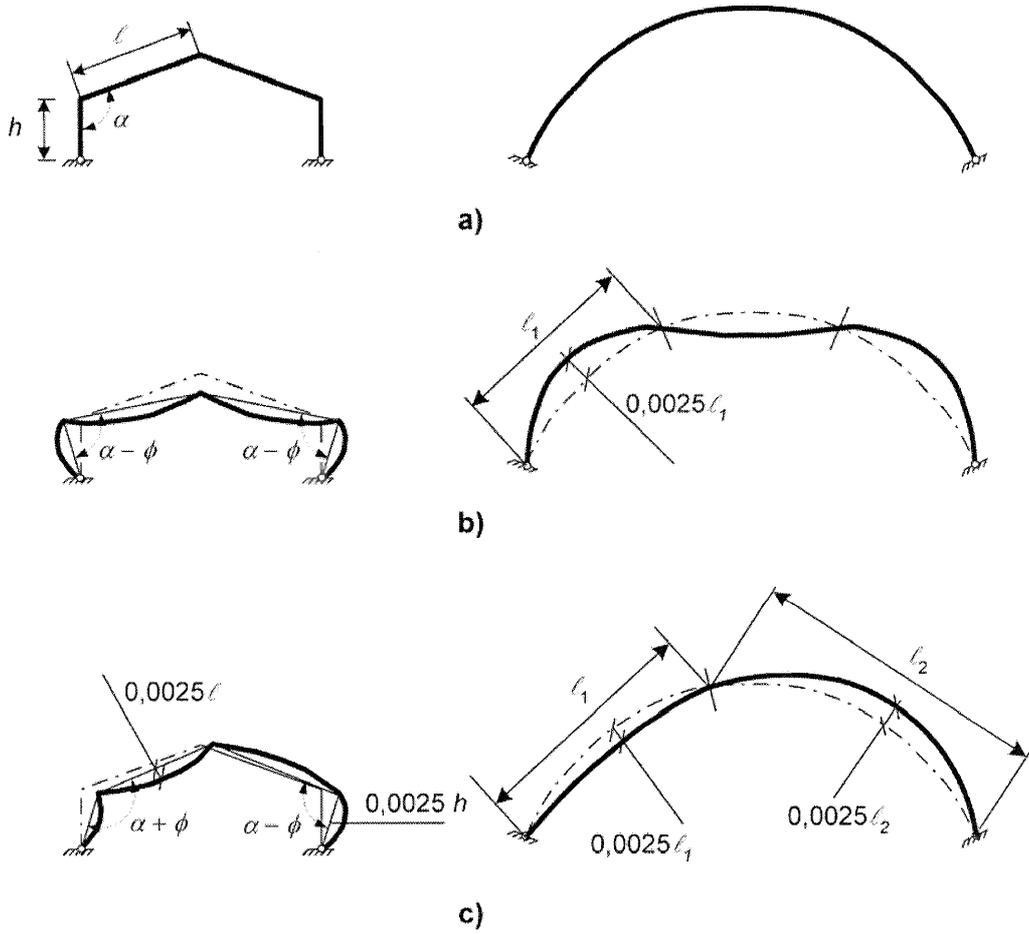


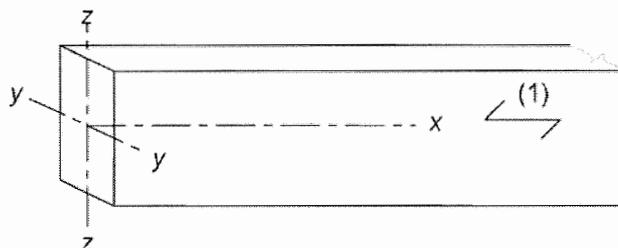
Figure 5.3 – Examples of assumed initial deviations in the geometry for a frame (a), corresponding to a symmetrical load (b) and non-symmetrical load (c)

## Section 6 Ultimate limit states

### 6.1 Design of cross-sections subjected to stress in one principal direction

#### 6.1.1 General

(1) Clause 6.1 applies to straight solid timber, glued laminated timber or wood-based structural products of constant cross-section, whose grain runs essentially parallel to the length of the member. The member is assumed to be subjected to stresses in the direction of only one of its principal axes (see Figure 6.1).



Key:  
(1) direction of grain

Figure 6.1 – Member Axes

#### 6.1.2 Tension parallel to the grain

(1)P The following expression shall be satisfied:

$$\sigma_{t,0,d} \leq f_{t,0,d} \quad (6.1)$$

where:

$\sigma_{t,0,d}$  is the design tensile stress along the grain;  
 $f_{t,0,d}$  is the design tensile strength along the grain.

#### 6.1.3 Tension perpendicular to the grain

(1)P The effect of member size shall be taken into account.

#### 6.1.4 Compression parallel to the grain

(1)P The following expression shall be satisfied:

$$\sigma_{c,0,d} \leq f_{c,0,d} \quad (6.2)$$

where:

$\sigma_{c,0,d}$  is the design compressive stress along the grain;  
 $f_{c,0,d}$  is the design compressive strength along the grain.

NOTE: Rules for the instability of members are given in 6.3.

#### 6.1.5 Compression perpendicular to the grain

$\boxed{A1}$  (1)P The following expression shall be satisfied:

$$\sigma_{c,90,d} \leq k_{c,90} f_{c,90,d} \quad (6.3)$$

with:  $\boxed{A1}$

$$\boxed{A1} \sigma_{c,90,d} = \frac{F_{c,90,d}}{A_{ef}} \quad (6.4)$$

where:

- $\sigma_{c,90,d}$  is the design compressive stress in the effective contact area perpendicular to the grain;
- $F_{c,90,d}$  is the design compressive load perpendicular to the grain;
- $A_{ef}$  is the effective contact area in compression perpendicular to the grain;
- $f_{c,90,d}$  is the design compressive strength perpendicular to the grain;
- $k_{c,90}$  is a factor taking into account the load configuration, the possibility of splitting and the degree of compressive deformation.

The effective contact area perpendicular to the grain,  $A_{ef}$ , should be determined taking into account an effective contact length parallel to the grain, where the actual contact length,  $\ell$ , at each side is increased by 30 mm, but not more than  $a$ ,  $\ell$  or  $\ell_1/2$ , see Figure 6.2.

(2) The value of  $k_{c,90}$  should be taken as 1,0 unless the conditions in the following paragraphs apply. In these cases the higher value of  $k_{c,90}$  specified may be taken, with a limiting value of  $k_{c,90} = 1,75$ .

(3) For members on continuous supports, provided that  $\ell_1 \geq 2h$ , see Figure 6.2a, the value of  $k_{c,90}$  should be taken as:

- $k_{c,90} = 1,25$  for solid softwood timber
- $k_{c,90} = 1,5$  for glued laminated softwood timber

where  $h$  is the depth of the member and  $\ell$  is the contact length.

(4) For members on discrete supports, provided that  $\ell_1 \geq 2h$ , see Figure 6.2b, the value of  $k_{c,90}$  should be taken as:

- $k_{c,90} = 1,5$  for solid softwood timber
- $k_{c,90} = 1,75$  for glued laminated softwood timber provided that  $\ell \leq 400$  mm

where  $h$  is the depth of the member and  $\ell$  is the contact length.

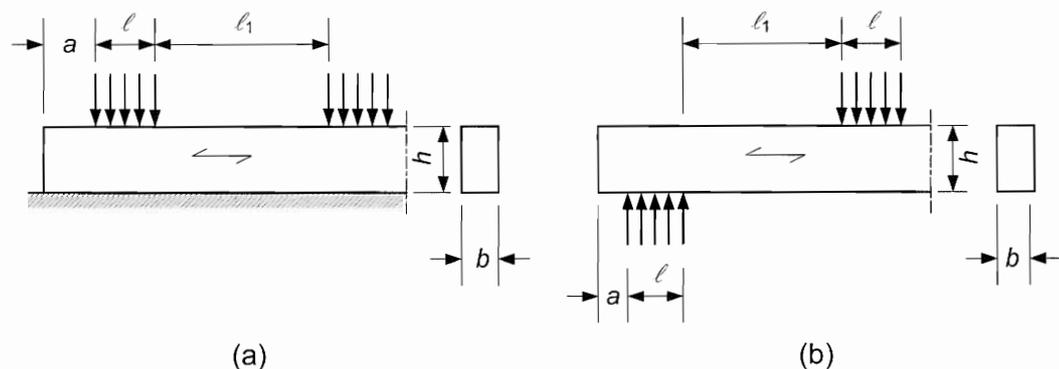


Figure 6.2 – Member on (a) continuous and (b) discrete supports

$\boxed{A1}$

### 6.1.6 Bending

(1)P The following expressions shall be satisfied:

$$\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.11)$$

$$k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.12)$$

where:

$\sigma_{m,y,d}$  and  $\sigma_{m,z,d}$  are the design bending stresses about the principal axes as shown in Figure 6.1;

$f_{m,y,d}$  and  $f_{m,z,d}$  are the corresponding design bending strengths.

NOTE: The factor  $k_m$  makes allowance for re-distribution of stresses and the effect of inhomogeneities of the material in a cross-section.

(2) The value of the factor  $k_m$  should be taken as follows:

For solid timber, glued laminated timber and LVL:

for rectangular sections:  $k_m = 0,7$

for other cross-sections:  $k_m = 1,0$

For other wood-based structural products, for all cross-sections:  $k_m = 1,0$

(3)P A check shall also be made of the instability condition (see 6.3).

### 6.1.7 Shear

**A1** (1)P For shear with a stress component parallel to the grain, see Figure 6.5(a), as well as for shear with both stress components perpendicular to the grain, see Figure 6.5(b), the following expression shall be satisfied:

$$\tau_d \leq f_{v,d} \quad (6.13)$$

where:

$\tau_d$  is the design shear stress;

$f_{v,d}$  is the design shear strength for the actual condition.

NOTE: The shear strength for rolling shear is approximately equal to twice the tensile strength perpendicular to grain.

(2) For the verification of shear resistance of members in bending, the influence of cracks should be taken into account using an effective width of the member given as:

$$b_{ef} = k_{cr} b \quad (6.13a)$$

where  $b$  is the width of the relevant section of the member.

NOTE: The recommended value for  $k_{cr}$  is given as

$k_{cr} = 0,67$  for solid timber

$k_{cr} = 0,67$  for glued laminated timber

$k_{cr} = 1,0$  for other wood-based products in accordance with EN 13986 and EN 14374.

Information on the National choice may be found in the National annex. **A1**

A1

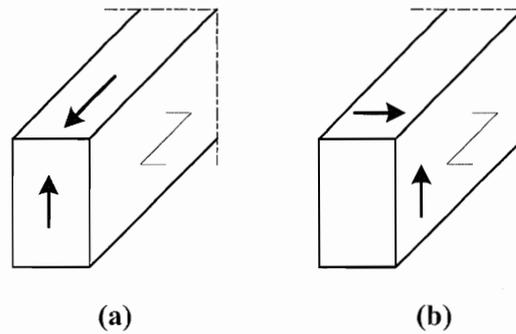


Figure 6.5 – (a) Member with a shear stress component parallel to the grain (b) Member with both stress components perpendicular to the grain (rolling shear)

(3) At supports, the contribution to the total shear force of a concentrated load  $F$  acting on the top side of the beam and within a distance  $h$  or  $h_{ef}$  from the edge of the support may be disregarded (see Figure 6.6). For beams with a notch at the support this reduction in the shear force applies only when the notch is on the opposite side to the support.

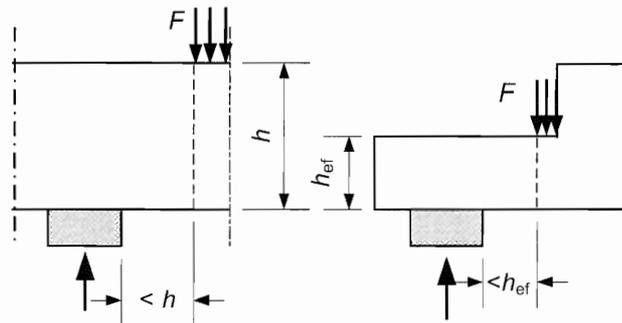


Figure 6.6 – Conditions at a support, for which the concentrated force  $F$  may be disregarded in the calculation of the shear force A1

### 6.1.8 Torsion

(1)P The following expression shall be satisfied:

$$\tau_{\text{tor,d}} \leq k_{\text{shape}} f_{\text{v,d}} \quad (6.14)$$

with

$$k_{\text{shape}} = \begin{cases} 1,2 & \text{for a circular cross section} \\ \min \left\{ \begin{array}{l} 1+0,15 \frac{h}{b} \\ 2,0 \end{array} \right. & \text{for a rectangular cross section} \end{cases} \quad (6.15)$$

where:

$\tau_{\text{tor,d}}$  is the design torsional stress;

$f_{\text{v,d}}$  is the design shear strength;

$k_{\text{shape}}$  is a factor depending on the shape of the cross-section;

$h$  is the larger cross-sectional dimension;

$b$  is the smaller cross-sectional dimension.

## 6.2 Design of cross-sections subjected to combined stresses

### 6.2.1 General

(1)P Clause 6.2 applies to straight solid timber, glued laminated timber or wood-based structural products of constant cross-section, whose grain runs essentially parallel to the length of the member. The member is assumed to be subjected to stresses from combined actions or to stresses acting in two or three of its principal axes.

### 6.2.2 Compression stresses at an angle to the grain

(1)P Interaction of compressive stresses in two or more directions shall be taken into account.

(2) The compressive stresses at an angle  $\alpha$  to the grain, (see Figure 6.7), should satisfy the following expression:

$$\sigma_{c,\alpha,d} \leq \frac{f_{c,0,d}}{\frac{f_{c,0,d}}{k_{c,90} f_{c,90,d}} \sin^2 \alpha + \cos^2 \alpha} \quad (6.16)$$

where:

$\sigma_{c,\alpha,d}$  is the compressive stress at an angle  $\alpha$  to the grain;

$k_{c,90}$  is a factor given in 6.1.5 taking into account the effect of any of stresses perpendicular to the grain.

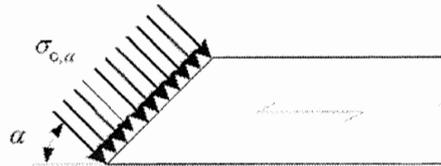


Figure 6.7 – Compressive stresses at an angle to the grain

### 6.2.3 Combined bending and axial tension

(1)P The following expressions shall be satisfied:

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.17)$$

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.18)$$

(2) The values of  $k_m$  given in 6.1.6 apply.

### 6.2.4 Combined bending and axial compression

(1)P The following expressions shall be satisfied:

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.19)$$

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.20)$$

(2)P The values of  $k_m$  given in 6.1.6 apply.

NOTE: To check the instability condition, a method is given in 6.3.

### 6.3 Stability of members

#### 6.3.1 General

(1)P The bending stresses due to initial curvature, eccentricities and induced deflection shall be taken into account, in addition to those due to any lateral load.

(2)P Column stability and lateral torsional stability shall be verified using the characteristic properties, e.g.  $E_{0,05}$

(3) The stability of columns subjected to either compression or combined compression and bending should be verified in accordance with 6.3.2.

(4) The lateral torsional stability of beams subjected to either bending or combined bending and compression should be verified in accordance with 6.3.3.

#### 6.3.2 Columns subjected to either compression or combined compression and bending

(1) The relative slenderness ratios should be taken as:

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} \quad (6.21)$$

and

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} \quad (6.22)$$

where:

$\lambda_y$  and  $\lambda_{rel,y}$  are slenderness ratios corresponding to bending about the y-axis (deflection in the z-direction);

$\lambda_z$  and  $\lambda_{rel,z}$  are slenderness ratios corresponding to bending about the z-axis (deflection in the y-direction);

$E_{0,05}$  is the fifth percentile value of the modulus of elasticity parallel to the grain.

(2) Where both  $\lambda_{rel,z} \leq 0,3$  and  $\lambda_{rel,y} \leq 0,3$  the stresses should satisfy the expressions (6.19) and (6.20) in 6.2.4.

(3) In all other cases the stresses, which will be increased due to deflection, should satisfy the following expressions:

$$\frac{\sigma_{c,0,d}}{k_{c,y} f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.23)$$

$$\frac{\sigma_{c,0,d}}{k_{c,z} f_{c,0,d}} + k_m \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1 \quad (6.24)$$

where the symbols are defined as follows:

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}} \quad (6.25)$$

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} \quad (6.26)$$

$$k_y = 0,5 \left( 1 + \beta_c (\lambda_{rel,y} - 0,3) + \lambda_{rel,y}^2 \right) \quad (6.27)$$

$$k_z = 0,5 \left( 1 + \beta_c (\lambda_{rel,z} - 0,3) + \lambda_{rel,z}^2 \right) \quad (6.28)$$

where:

$\beta_c$  is a factor for members within the straightness limits defined in Section 10:

$$\beta_c = \begin{cases} 0,2 & \text{for solid timber} \\ 0,1 & \text{for glued laminated timber and LVL} \end{cases} \quad (6.29)$$

$k_m$  as given in 6.1.6.

### 6.3.3 Beams subjected to either bending or combined bending and compression

(1)P Lateral torsional stability shall be verified both in the case where only a moment  $M_y$  exists about the strong axis  $y$  and where a combination of moment  $M_y$  and compressive force  $N_c$  exists.

(2) The relative slenderness for bending should be taken as:

$$\lambda_{rel,m} = \sqrt{\frac{f_{m,k}}{\sigma_{m,crit}}} \quad (6.30)$$

where  $\sigma_{m,crit}$  is the critical bending stress calculated according to the classical theory of stability, using 5-percentile stiffness values.

The critical bending stress should be taken as:

$$\sigma_{m,crit} = \frac{M_{y,crit}}{W_y} = \frac{\pi \sqrt{E_{0,05} I_z G_{0,05} I_{tor}}}{\ell_{ef} W_y} \quad (6.31)$$

where:

$E_{0,05}$  is the fifth percentile value of modulus of elasticity parallel to grain;

$G_{0,05}$  is the fifth percentile value of shear modulus parallel to grain;

$I_z$  is the second moment of area about the weak axis  $z$ .

$I_{tor}$  is the torsional moment of inertia;

$\ell_{ef}$  is the effective length of the beam, depending on the support conditions and the load configuration, according to Table 6.1;

$W_y$  is the section modulus about the strong axis  $y$ .

For softwood with solid rectangular cross-section,  $\sigma_{m,crit}$  should be taken as:

$$\sigma_{m,crit} = \frac{0,78 b^2}{h \ell_{ef}} E_{0,05} \quad (6.32)$$

where:

$b$  is the width of the beam;

$h$  is the depth of the beam.

(3) In the case where only a moment  $M_y$  exists about the strong axis  $y$ , the stresses should satisfy the following expression:

$$\sigma_{m,d} \leq k_{crit} f_{m,d} \quad (6.33)$$

where:

$\sigma_{m,d}$  is the design bending stress;

$f_{m,d}$  is the design bending strength;

$k_{crit}$  is a factor which takes into account the reduced bending strength due to lateral buckling.

**Table 6.1 – Effective length as a ratio of the span**

Beam type	Loading type	$\ell_{ef}/\ell^a$
Simply supported	Constant moment	1,0
	Uniformly distributed load	0,9
	Concentrated force at the middle of the span	0,8
Cantilever	Uniformly distributed load	0,5
	Concentrated force at the free end	0,8

<sup>a</sup> The ratio between the effective length  $\ell_{ef}$  and the span  $\ell$  is valid for a beam with torsionally restrained supports and loaded at the centre of gravity. If the load is applied at the compression edge of the beam,  $\ell_{ef}$  should be increased by  $2h$  and may be decreased by  $0,5h$  for a load at the tension edge of the beam.

(4) For beams with an initial lateral deviation from straightness within the limits defined in Section 10,  $k_{crit}$  may be determined from expression (6.34)

$$k_{crit} = \begin{cases} 1 & \text{for } \lambda_{rel,m} \leq 0,75 \\ 1,56 - 0,75\lambda_{rel,m} & \text{for } 0,75 < \lambda_{rel,m} \leq 1,4 \\ \frac{1}{\lambda_{rel,m}^2} & \text{for } 1,4 < \lambda_{rel,m} \end{cases} \quad (6.34)$$

(5) The factor  $k_{crit}$  may be taken as 1,0 for a beam where lateral displacement of its compressive edge is prevented throughout its length and where torsional rotation is prevented at its supports.

**[A1]** (6) In the case where a combination of moment  $M_y$  about the strong axis  $y$  and compressive force  $N_c$  exists, the stresses should satisfy the following expression:

$$\left( \frac{\sigma_{m,d}}{k_{crit} f_{m,d}} \right)^2 + \frac{\sigma_{c,0,d}}{k_{c,z} f_{c,0,d}} \leq 1 \quad (6.35)$$

where:

$\sigma_{m,d}$  is the design bending stress;

$\sigma_{c,0,d}$  is the design compressive stress parallel to grain;

$f_{c,0,d}$  is the design compressive strength parallel to grain;

$k_{c,z}$  is given by expression (6.26). **[A1]**

## 6.4 Design of cross-sections in members with varying cross-section or curved shape

### 6.4.1 General

(1)P The effects of combined axial force and bending moment shall be taken into account.

(2) The relevant parts of 6.2 and 6.3 should be verified.

(3) The stress at a cross-section from an axial force may be calculated from

$$\sigma_N = \frac{N}{A} \quad (6.36)$$

where:

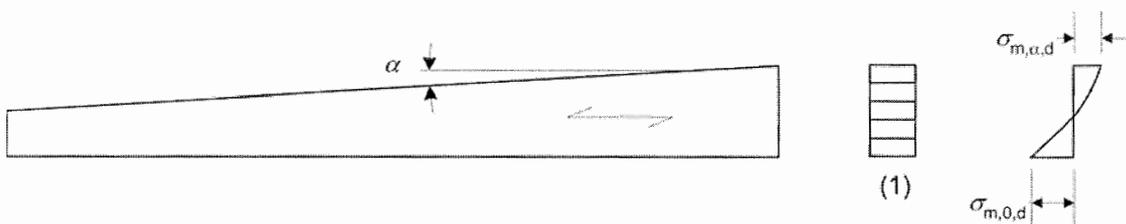
$\sigma_N$  is the axial stress;

$N$  is the axial force;

$A$  is the area of the cross-section.

### 6.4.2 Single tapered beams

(1)P The influence of the taper on the bending stresses parallel to the surface shall be taken into account.



Key:

(1) cross-section

Figure 6.8 – Single tapered beam

(2) The design bending stresses,  $\sigma_{m,\alpha,d}$  and  $\sigma_{m,0,d}$  (see Figure 6.8) may be taken as:

$$\sigma_{m,\alpha,d} = \sigma_{m,0,d} = \frac{6M_d}{bh^2} \quad (6.37)$$

At the outermost fibre of the tapered edge, the stresses should satisfy the following expression:

$$\sigma_{m,\alpha,d} \leq k_{m,\alpha} f_{m,d} \quad (6.38)$$

where:

$\sigma_{m,\alpha,d}$  is the design bending stress at an angle to grain;

$f_{m,d}$  is the design bending strength;

$k_{m,\alpha}$  should be calculated as:

For tensile stresses parallel to the tapered edge:

$$k_{m,\alpha} = \frac{1}{\sqrt{1 + \left( \frac{f_{m,d}}{0,75 f_{v,d}} \tan \alpha \right)^2 + \left( \frac{f_{m,d}}{f_{t,90,d}} \tan^2 \alpha \right)^2}} \quad (6.39)$$

For compressive stresses parallel to the tapered edge:

$$k_{m,\alpha} = \frac{1}{\sqrt{1 + \left( \frac{f_{m,d}}{1,5 f_{v,d}} \tan \alpha \right)^2 + \left( \frac{f_{m,d}}{f_{c,90,d}} \tan^2 \alpha \right)^2}} \quad (6.40)$$

### 6.4.3 Double tapered, curved and pitched cambered beams

(1) This clause applies only to glued laminated timber and LVL.

(2) The requirements of 6.4.2 apply to the parts of the beam which have a single taper.

(3) In the apex zone (see Figure 6.9), the bending stresses should satisfy the following expression:

$$\sigma_{m,d} \leq k_r f_{m,d} \quad (6.41)$$

where  $k_r$  takes into account the strength reduction due to bending of the laminates during production.

NOTE: In curved and pitched cambered beams the apex zone extends over the curved part of the beam

(4) The apex bending stress should be calculated as follows:

$$\sigma_{m,d} = k_\ell \frac{6M_{ap,d}}{bh_{ap}^2} \quad (6.42)$$

with:

$$k_\ell = k_1 + k_2 \left( \frac{h_{ap}}{r} \right) + k_3 \left( \frac{h_{ap}}{r} \right)^2 + k_4 \left( \frac{h_{ap}}{r} \right)^3 \quad (6.43)$$

$$k_1 = 1 + 1,4 \tan \alpha_{ap} + 5,4 \tan^2 \alpha_{ap} \quad (6.44)$$

$$k_2 = 0,35 - 8 \tan \alpha_{ap} \quad (6.45)$$

$$k_3 = 0,6 + 8,3 \tan \alpha_{ap} - 7,8 \tan^2 \alpha_{ap} \quad (6.46)$$

$$k_4 = 6 \tan^2 \alpha_{ap} \quad (6.47)$$

$$r = r_{in} + 0,5 h_{ap} \quad (6.48)$$

where:

$M_{ap,d}$  is the design moment at the apex;

$h_{ap}$  is the depth of the beam at the apex, see Figure 6.9;

$b$  is the width of the beam;

$r_{in}$  is the inner radius, see Figure 6.9;

$\alpha_{ap}$  is the angle of the taper in the middle of the apex zone, see Figure 6.9.

(5) For double tapered beams  $k_r = 1,0$ . For curved and pitched cambered beams  $k_r$  should be taken as:

$$k_r = \begin{cases} 1 & \text{for } \frac{r_{in}}{t} \geq 240 \\ 0,76 + 0,001 \frac{r_{in}}{t} & \text{for } \frac{r_{in}}{t} < 240 \end{cases} \quad (6.49)$$

where

$r_{in}$  is the inner radius, see Figure 6.9;

$t$  is the lamination thickness.

(6) In the apex zone the greatest tensile stress perpendicular to the grain,  $\sigma_{t,90,d}$ , should satisfy the following expression:

$$\sigma_{t,90,d} \leq k_{dis} k_{vol} f_{t,90,d} \quad (6.50)$$

with

$$k_{vol} = \begin{cases} 1,0 & \text{for solid timber} \\ \left( \frac{V_0}{V} \right)^{0,2} & \text{for glued laminated timber and LVL with} \\ & \text{all veneers parallel to the beam axis} \end{cases} \quad (6.51)$$

$$k_{dis} = \begin{cases} 1,4 & \text{for double tapered and curved beams} \\ 1,7 & \text{for pitched cambered beams} \end{cases} \quad (6.52)$$

where:

$k_{dis}$  is a factor which takes into account the effect of the stress distribution in the apex zone;

$k_{vol}$  is a volume factor;

$f_{t,90,d}$  is the design tensile strength perpendicular to the grain;

$V_0$  is the reference volume of 0,01m<sup>3</sup>;

$V$  is the stressed volume of the apex zone, in m<sup>3</sup>, (see Figure 6.9) and should not be taken greater than  $2V_b/3$ , where  $V_b$  is the total volume of the beam.

**[A1]** (7) For combined tension perpendicular to grain and shear the following expression should be satisfied: **[A1]**

$$\frac{\tau_d}{f_{v,d}} + \frac{\sigma_{t,90,d}}{k_{dis} k_{vol} f_{t,90,d}} \leq 1 \quad (6.53)$$

where:

$\tau_d$  is the design shear stress;

$f_{v,d}$  is the design shear strength;

$\sigma_{t,90,d}$  is the design tensile stress perpendicular to grain;

$k_{dis}$  and  $k_{vol}$  are given in (6).

(8) The greatest tensile stress perpendicular to the grain due to the bending moment should be calculated as follows:

$$\sigma_{t,90,d} = k_p \frac{6 M_{ap,d}}{b h_{ap}^2} \quad (6.54)$$

or, as an alternative to expression (6.54), as

$$\sigma_{t,90,d} = k_p \frac{6 M_{ap,d}}{b h_{ap}^2} - 0,6 \frac{p_d}{b} \quad (6.55)$$

where:

$p_d$  is the uniformly distributed load acting on the top of the beam over the apex area;

$b$  is the width of the beam;

$M_{ap,d}$  is the design moment at apex resulting in tensile stresses parallel to the inner curved edge;

with:

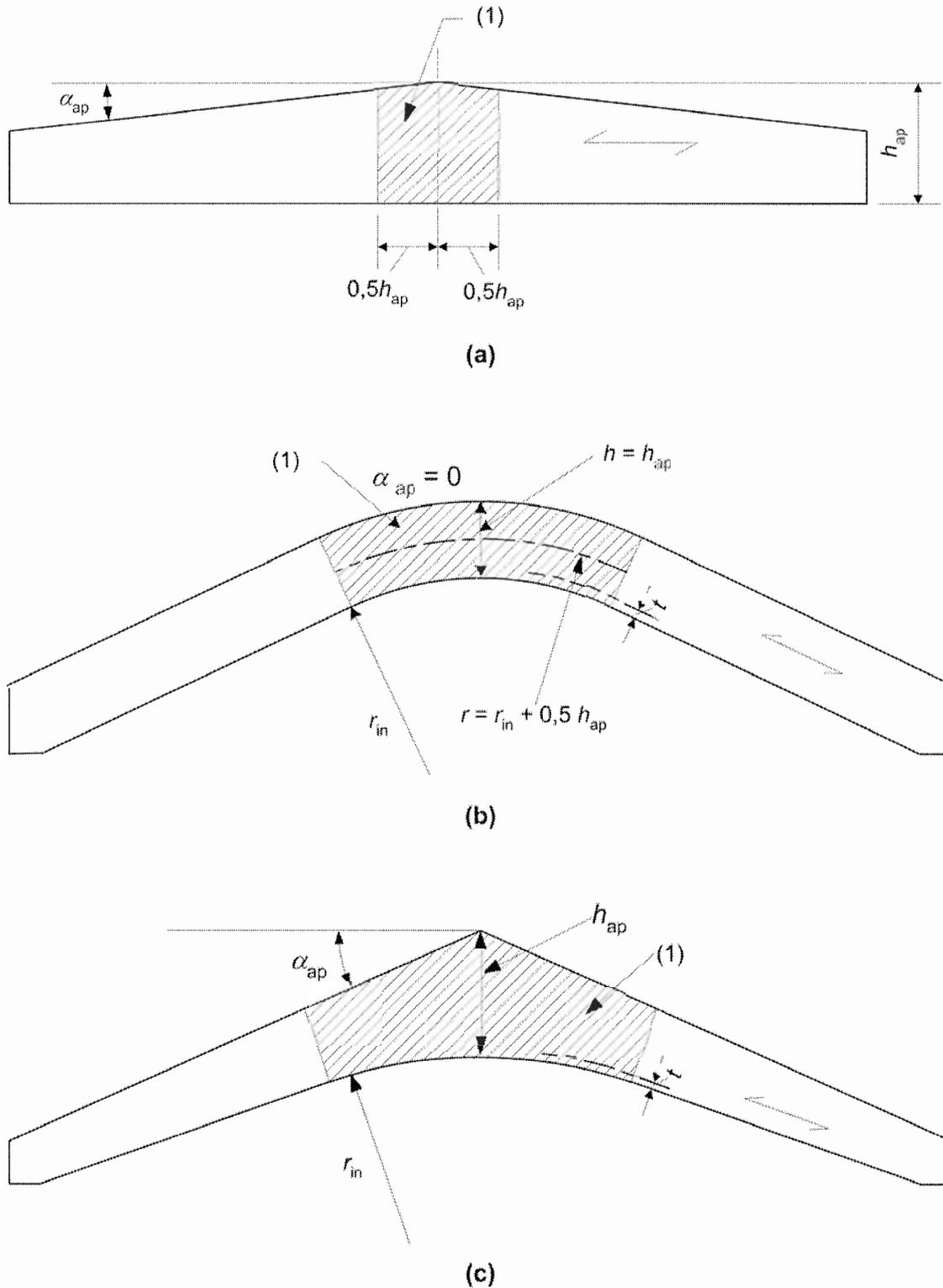
$$k_p = k_5 + k_6 \left( \frac{h_{ap}}{r} \right) + k_7 \left( \frac{h_{ap}}{r} \right)^2 \quad (6.56)$$

$$k_5 = 0,2 \tan \alpha_{ap} \quad (6.57)$$

$$k_6 = 0,25 - 1,5 \tan \alpha_{ap} + 2,6 \tan^2 \alpha_{ap} \quad (6.58)$$

$$k_7 = 2,1 \tan \alpha_{ap} - 4 \tan^2 \alpha_{ap} \quad (6.59)$$

Note: The recommended expression is (6.54). Information on the national choice between expressions (6.54) and (6.55) may be found in the National annex.



Key:  
 (1) Apex Zone

NOTE: In curved and pitched cambered beams the apex zone extends over the curved parts of the beam.

**Figure 6.9 – Double tapered (a), curved (b) and pitched cambered (c) beams with the fibre direction parallel to the lower edge of the beam**

## 6.5 Notched members

### 6.5.1 General

(1)P The effects of stress concentrations at the notch shall be taken into account in the strength verification of members.

(2) The effect of stress concentrations may be disregarded in the following cases:

- tension or compression parallel to the grain;
- bending with tensile stresses at the notch if the taper is not steeper than  $1:i = 1:10$ , that is  $i \geq 10$ , see Figure 6.10a;
- bending with compressive stresses at the notch, see Figure 6.10b.

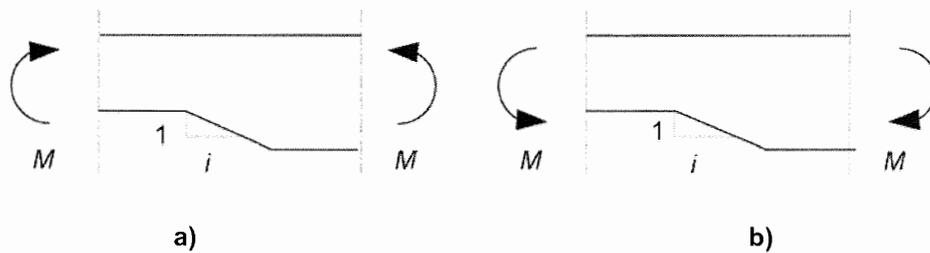


Figure 6.10 – Bending at a notch: a) with tensile stresses at the notch, b) with compressive stresses at the notch

### 6.5.2 Beams with a notch at the support

(1) For beams with rectangular cross-sections and where grain runs essentially parallel to the length of the member, the shear stresses at the notched support should be calculated using the effective (reduced) depth  $h_{ef}$  (see Figure 6.11).

(2) It should be verified that

$$\tau_d = \frac{1,5V}{bh_{ef}} \leq k_v f_{v,d} \quad (6.60)$$

where  $k_v$  is a reduction factor defined as follows:

- For beams notched at the opposite side to the support (see Figure 6.11b)

$$k_v = 1,0 \quad (6.61)$$

- For beams notched on the same side as the support (see Figure 6.11a)

$$k_v = \min \left\{ \begin{array}{l} 1 \\ k_n \left( 1 + \frac{1,1 i^{1,5}}{\sqrt{h}} \right) \\ \sqrt{h} \left( \sqrt{\alpha(1-\alpha)} + 0,8 \frac{x}{h} \sqrt{\frac{1}{\alpha} - \alpha^2} \right) \end{array} \right. \quad (6.62)$$

where:

- $i$  is the notch inclination (see Figure 6.11a);  
 $h$  is the beam depth in mm;  
 $x$  is the distance from the line of action of the support reaction to the corner of the notch, in mm;

$$\alpha = \frac{ci}{h}$$

$$k_n = \begin{cases} 4,5 & \text{for LVL} \\ 5 & \text{for solid timber} \\ 6,5 & \text{for glued laminated timber} \end{cases} \quad (6.63)$$

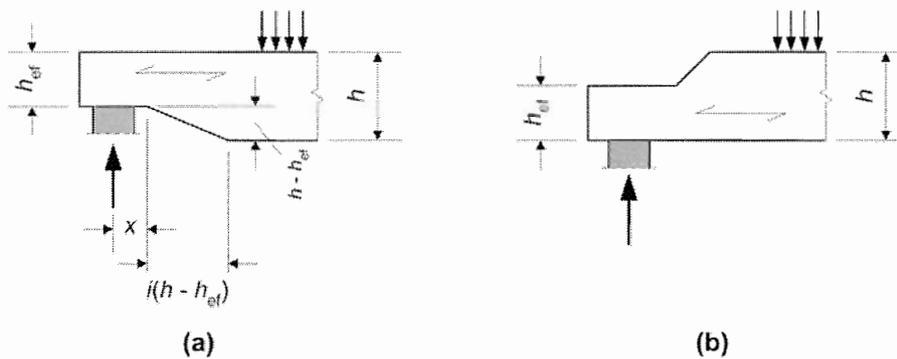


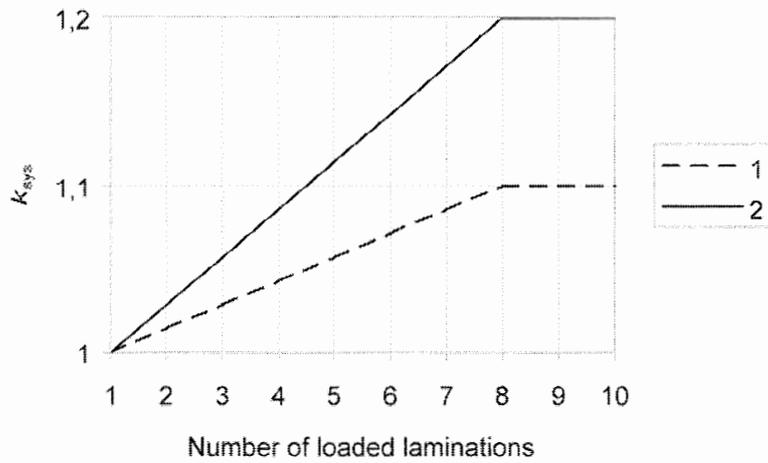
Figure 6.11 – End-notched beams

## 6.6 System strength

- (1) When several equally spaced similar members, components or assemblies are laterally connected by a continuous load distribution system, the member strength properties may be multiplied by a system strength factor  $k_{\text{sys}}$ .
- (2) Provided the continuous load-distribution system is capable of transferring the loads from one member to the neighbouring members, the factor  $k_{\text{sys}}$  should be 1,1.
- (3) The strength verification of the load distribution system should be carried out assuming the loads are of short-term duration.

NOTE: For roof trusses with a maximum centre to centre distance of 1,2 m it may be assumed that tiling battens, purlins or panels can transfer the load to the neighbouring trusses provided that these load-distribution members are continuous over at least two spans, and any joints are staggered.

- (4) For laminated timber decks or floors the values of  $k_{\text{sys}}$  given in Figure 6.12 should be used.



Key:  
1 Nailed or screwed laminations  
2 Laminations pre-stressed or glued together

Figure 6.12 – System strength factor  $k_{sys}$  for laminated deck plates of solid timber or glued laminated members

## Section 7 Serviceability limit states

### 7.1 Joint slip

(1) For joints made with dowel-type fasteners the slip modulus  $K_{ser}$  per shear plane per fastener under service load should be taken from Table 7.1 with  $\rho_m$  in kg/m<sup>3</sup> and  $d$  or  $d_c$  in mm. For the definition of  $d_c$ , see EN 13271.

NOTE: In EN 26891 the symbol used is  $k_s$  instead of  $K_{ser}$ .

**Table 7.1 – Values of  $K_{ser}$  for fasteners and connectors in N/mm in timber-to-timber and wood-based panel-to-timber connections**

Fastener type	$K_{ser}$
Dowels Bolts with or without clearance <sup>a</sup> Screws Nails (with pre-drilling)	$\rho_m^{1,5} d/23$
Nails (without pre-drilling)	$\rho_m^{1,5} d^{0,8}/30$
Staples	$\rho_m^{1,5} d^{0,8}/80$
Split-ring connectors type A according to EN 912 Shear-plate connectors type B according to EN 912	$\rho_m d_c/2$
Toothed-plate connectors:	
– Connectors types C1 to C9 according to EN 912	$1,5\rho_m d_c/4$
– Connectors type C10 and C11 according to EN 912	$\rho_m d_c/2$
<sup>a</sup> The clearance should be added separately to the deformation.	

(2) If the mean densities  $\rho_{m,1}$  and  $\rho_{m,2}$  of the two jointed wood-based members are different then  $\rho_m$  in the above expressions should be taken as

$$\rho_m = \sqrt{\rho_{m,1}\rho_{m,2}} \quad (7.1)$$

(3) For steel-to-timber or concrete-to-timber connections,  $K_{ser}$  should be based on  $\rho_m$  for the timber member and may be multiplied by 2,0.

### 7.2 Limiting values for deflections of beams

(1) The components of deflection resulting from a combination of actions (see 2.2.3(5)) are shown in Figure 7.1, where the symbols are defined as follows, see 2.2.3:

- $w_c$  is the precamber (if applied);
- $w_{inst}$  is the instantaneous deflection;
- $w_{creep}$  is the creep deflection;
- $w_{fin}$  is the final deflection;
- $w_{net,fin}$  is the net final deflection.

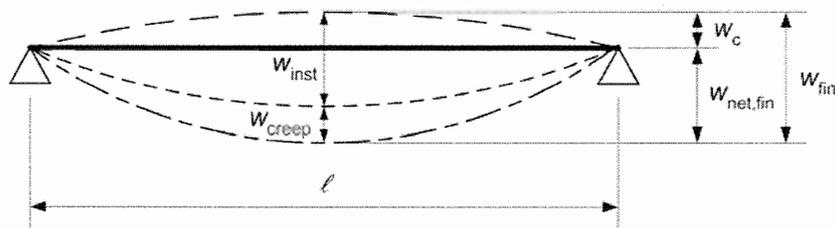


Figure 7.1 – Components of deflection

(2) The net deflection below a straight line between the supports,  $w_{net,fin}$ , should be taken as:

$$w_{net,fin} = w_{inst} + w_{creep} - w_c = w_{fin} - w_c \quad (7.2)$$

NOTE: The recommended range of limiting values of deflections for beams with span  $l$  is given in Table 7.2 depending upon the level of deformation deemed to be acceptable. Information on National choice may be found in the National annex.

Table 7.2 – Examples of limiting values for deflections of beams

	$w_{inst}$	$w_{net,fin}$	$w_{fin}$
Beam on two supports	$l/300$ to $l/500$	$l/250$ to $l/350$	$l/150$ to $l/300$
Cantilevering beams	$l/150$ to $l/250$	$l/125$ to $l/175$	$l/75$ to $l/150$

### 7.3 Vibrations

#### 7.3.1 General

(1)P It shall be ensured that the actions which can be reasonably anticipated on a member, component or structure, do not cause vibrations that can impair the function of the structure or cause unacceptable discomfort to the users.

(2) The vibration level should be estimated by measurements or by calculation taking into account the expected stiffness of the member, component or structure and the modal damping ratio.

(3) For floors, unless other values are proven to be more appropriate, a modal damping ratio of  $\zeta = 0,01$  (i.e 1 %) should be assumed.

#### 7.3.2 Vibrations from machinery

(1)P Vibrations caused by rotating machinery and other operational equipment shall be limited for the unfavourable combinations of permanent load and variable loads that can be expected.

(2) For floors, acceptable levels for continuous vibration should be taken from figure 5a in Appendix A of ISO 2631-2 with a multiplying factor of 1,0.

#### 7.3.3 Residential floors

(1) For residential floors with a fundamental frequency less than 8Hz ( $f_1 \leq 8\text{Hz}$ ) a special investigation should be made.

(2) For residential floors with a fundamental frequency greater than 8 Hz ( $f_1 > 8\text{ Hz}$ ) the following requirements should be satisfied:

$$\frac{w}{F} \leq a \text{ mm/kN} \quad (7.3)$$

and

$$v \leq b^{(f_1 \zeta^{-1})} \text{ m/(Ns}^2) \quad (7.4)$$

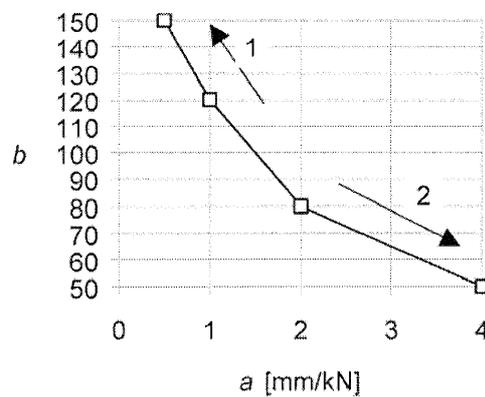
where:

$w$  is the maximum instantaneous vertical deflection caused by a vertical concentrated static force  $F$  applied at any point on the floor, taking account of load distribution;

$v$  is the unit impulse velocity response, i.e. the maximum initial value of the vertical floor vibration velocity (in m/s) caused by an ideal unit impulse (1 Ns) applied at the point of the floor giving maximum response. Components above 40 Hz may be disregarded;

$\zeta$  is the modal damping ratio.

NOTE: The recommended range of limiting values of  $a$  and  $b$  and the recommended relationship between  $a$  and  $b$  is given in Figure 7.2. Information on the National choice may be found in the National annex.



Key:  
1 Better performance  
2 Poorer performance

Figure 7.2 — Recommended range of and relationship between  $a$  and  $b$

(3) The calculations in 7.3.3(2) should be made under the assumption that the floor is unloaded, i.e., only the mass corresponding to the self-weight of the floor and other permanent actions.

(4) For a rectangular floor with overall dimensions  $\ell \times b$ , simply supported along all four edges and with timber beams having a span  $\ell$ , the fundamental frequency  $f_1$  may approximately be calculated as

$$f_1 = \frac{\pi}{2\ell^2} \sqrt{\frac{(EI)_\ell}{m}} \quad (7.5)$$

where:

$m$  is the mass per unit area in kg/m<sup>2</sup>;

$\ell$  is the floor span, in m;

$(EI)_\ell$  is the equivalent plate bending stiffness of the floor about an axis perpendicular to the beam direction, in Nm<sup>2</sup>/m.

(5) For a rectangular floor with overall dimensions  $b \times \ell$ , simply supported along all four edges, the value  $v$  may, as an approximation, be taken as:

$$v = \frac{4(0,4 + 0,6 n_{40})}{mb\ell + 200} \quad (7.6)$$

where:

- $v$  is the unit impulse velocity response, in  $\text{m}/(\text{Ns}^2)$ ;
- $n_{40}$  is the number of first-order modes with natural frequencies up to 40 Hz;
- $b$  is the floor width, in m;
- $m$  is the mass, in  $\text{kg}/\text{m}^2$ ;
- $\ell$  is the floor span, in m.

The value of  $n_{40}$  may be calculated from:

$$n_{40} = \left\{ \left[ \left( \frac{40}{f_1} \right)^2 - 1 \right] \left( \frac{b}{\ell} \right)^4 \frac{(EI)_\ell}{(EI)_b} \right\}^{0,25} \quad (7.7)$$

where  $(EI)_b$  is the equivalent plate bending stiffness, in  $\text{Nm}^2/\text{m}$ , of the floor about an axis parallel to the beams, where  $(EI)_b < (EI)_\ell$ .

## Section 8 Connections with metal fasteners

### 8.1 General

#### 8.1.1 Fastener requirements

(1)P Unless rules are given in this section, the characteristic load-carrying capacity, and the stiffness of the connections shall be determined from tests according to EN 1075, EN 1380, EN 1381, EN 26891 and EN 28970. If the relevant standards describe tension and compression tests, the tests for the determination of the characteristic load-carrying capacity shall be performed in tension.

#### 8.1.2 Multiple fastener connections

(1)P The arrangement and sizes of the fasteners in a connection, and the fastener spacings, edge and end distances shall be chosen so that the expected strength and stiffness can be obtained.

(2)P It shall be taken into account that the load-carrying capacity of a multiple fastener connection, consisting of fasteners of the same type and dimension, may be lower than the summation of the individual load-carrying capacities for each fastener.

(3) When a connection comprises different types of fasteners, or when the stiffness of the connections in respective shear planes of a multiple shear plane connection is different, their compatibility should be verified.

(4) For one row of fasteners parallel to the grain direction, the effective characteristic load-carrying capacity parallel to the row,  $F_{v,ef,Rk}$ , should be taken as:

$$F_{v,ef,Rk} = n_{ef} F_{v,Rk} \quad (8.1)$$

where:

$F_{v,ef,Rk}$  is the effective characteristic load-carrying capacity of one row of fasteners parallel to the grain;

$n_{ef}$  is the effective number of fasteners in line parallel to the grain;

$F_{v,Rk}$  is the characteristic load-carrying capacity of each fastener parallel to the grain.

NOTE: Values of  $n_{ef}$  for rows parallel to grain are given in 8.3.1.1(8) and 8.5.1.1(4).

(5) For a force acting at an angle to the direction of the row, it should be verified that the force component parallel to the row is less than or equal to the load-carrying capacity calculated according to expression (8.1).

#### 8.1.3 Multiple shear plane connections

(1) In multiple shear plane connections the resistance of each shear plane should be determined by assuming that each shear plane is part of a series of three-member connections.

**A1** (2) To be able to combine the resistance from individual shear planes in a multiple shear plane connection, the governing failure mode of the fasteners in the respective shear planes should be compatible with each other and should not consist of a combination of failure modes (a), (b), (g) and (h) from Figure 8.2 or modes (c), (f) and (j/l) from Figure 8.3 with the other failure modes. **A1**

#### 8.1.4 Connection forces at an angle to the grain

(1)P When a force in a connection acts at an angle to the grain, (see Figure 8.1), the possibility

of splitting caused by the tension force component,  $F_{Ed} \sin \alpha$ , perpendicular to the grain, shall be taken into account.

(2)P To take account of the possibility of splitting caused by the tension force component,  $F_{Ed} \sin \alpha$ , perpendicular to the grain, the following shall be satisfied:

$$F_{v,Ed} \leq F_{90,Rd} \quad (8.2)$$

with

$$F_{v,Ed} = \max \begin{cases} F_{v,Ed,1} \\ F_{v,Ed,2} \end{cases} \quad (8.3)$$

where:

$F_{90,Rd}$  is the design splitting capacity, calculated from the characteristic splitting capacity  $F_{90,Rk}$  according to 2.4.3;

$F_{v,Ed,1}$ ,  $F_{v,Ed,2}$  are the design shear forces on either side of the connection. (see Figure 8.1).

(3) For softwoods, the characteristic splitting capacity for the arrangement shown in Figure 8.1 should be taken as:

$$F_{90,Rk} = 14 b w \sqrt{\frac{h_e}{\left(1 - \frac{h_e}{h}\right)}} \quad (8.4)$$

where:

$$w = \begin{cases} \max \left\{ \left( \frac{w_{pl}}{100} \right)^{0,35} \right. & \text{for punched metal plate fasteners} \\ 1 & \text{for all other fasteners} \end{cases} \quad (8.5)$$

and:

$F_{90,Rk}$  is the characteristic splitting capacity, in N;

$w$  is a modification factor;

$h_e$  is the loaded edge distance to the centre of the most distant fastener or to the edge of the punched metal plate fastener, in mm;

$h$  is the timber member height, in mm;

$b$  is the member thickness, in mm;

$w_{pl}$  is the width of the punched metal plate fastener parallel to the grain, in mm.

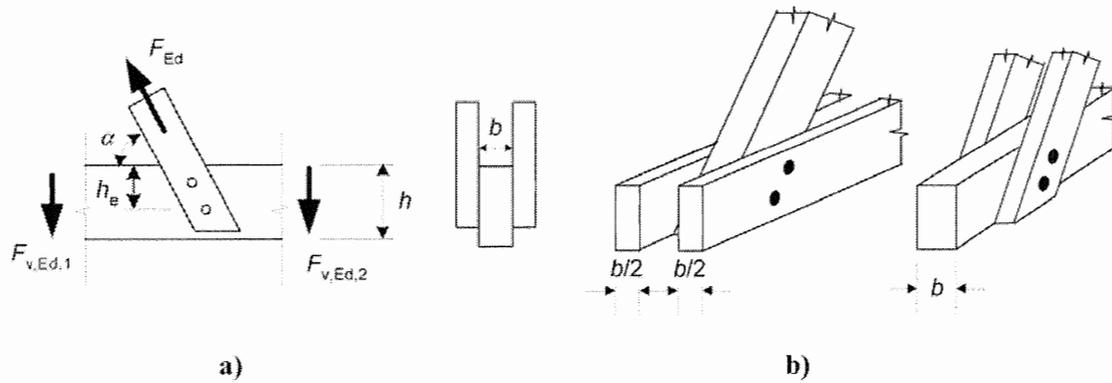


Figure 8.1 – Inclined force transmitted by a connection

### 8.1.5 Alternating connection forces

(1)P The characteristic load-carrying capacity of a connection shall be reduced if the connection is subject to alternating internal forces due to long-term or medium-term actions.

(2)The effect on connection strength of long-term or medium-term actions alternating between a tensile design force  $F_{t,Ed}$  and a compressive design force  $F_{c,Ed}$  should be taken into account by designing the connection for  $(F_{t,Ed} + 0,5F_{c,Ed})$  and  $(F_{c,Ed} + 0,5F_{t,Ed})$ .

## 8.2 Lateral load-carrying capacity of metal dowel-type fasteners

### 8.2.1 General

(1)P For the determination of the characteristic load-carrying capacity of connections with metal dowel-type fasteners the contributions of the yield strength, the embedment strength, and the withdrawal strength of the fastener shall be considered.

### 8.2.2 Timber-to-timber and panel-to-timber connections

(1) The characteristic load-carrying capacity for nails, staples, bolts, dowels and screws per shear plane per fastener, should be taken as the minimum value found from the following expressions:

– For fasteners in single shear

$$F_{v,Rk} = \min \left\{ \begin{array}{l} f_{h,1,k} t_1 d \quad (a) \\ f_{h,2,k} t_2 d \quad (b) \\ \frac{f_{h,1,k} t_1 d}{1 + \beta} \left[ \sqrt{\beta + 2\beta^2 \left[ 1 + \frac{t_2}{t_1} + \left( \frac{t_2}{t_1} \right)^2 \right] + \beta^3 \left( \frac{t_2}{t_1} \right)^2} - \beta \left( 1 + \frac{t_2}{t_1} \right) \right] + \frac{F_{ax,Rk}}{4} \quad (c) \\ 1,05 \frac{f_{h,1,k} t_1 d}{2 + \beta} \left[ \sqrt{2\beta(1 + \beta) + \frac{4\beta(2 + \beta)M_{y,Rk}}{f_{h,1,k} d t_1^2}} - \beta \right] + \frac{F_{ax,Rk}}{4} \quad (d) \\ 1,05 \frac{f_{h,1,k} t_2 d}{1 + 2\beta} \left[ \sqrt{2\beta^2(1 + \beta) + \frac{4\beta(1 + 2\beta)M_{y,Rk}}{f_{h,1,k} d t_2^2}} - \beta \right] + \frac{F_{ax,Rk}}{4} \quad (e) \\ 1,15 \sqrt{\frac{2\beta}{1 + \beta}} \sqrt{2M_{y,Rk} f_{h,1,k} d} + \frac{F_{ax,Rk}}{4} \quad (f) \end{array} \right. \quad (8.6)$$

– For fasteners in double shear:

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k} t_1 d & \text{(g)} \\ 0,5 f_{h,2,k} t_2 d & \text{(h)} \\ 1,05 \frac{f_{h,1,k} t_1 d}{2 + \beta} \left[ \sqrt{2\beta(1 + \beta) + \frac{4\beta(2 + \beta)M_{y,Rk}}{f_{h,1,k} d t_1^2}} - \beta \right] + \frac{F_{ax,Rk}}{4} & \text{(j)} \\ 1,15 \sqrt{\frac{2\beta}{1 + \beta}} \sqrt{2M_{y,Rk} f_{h,1,k} d} + \frac{F_{ax,Rk}}{4} & \text{(k)} \end{cases} \quad (8.7)$$

with

$$\beta = \frac{f_{h,2,k}}{f_{h,1,k}} \quad (8.8)$$

where:

- $F_{v,Rk}$  is the characteristic load-carrying capacity per shear plane per fastener;
- $t_i$  is the timber or board thickness or penetration depth, with  $i$  either 1 or 2, see also 8.3 to 8.7 ;
- $f_{h,i,k}$  is the characteristic embedment strength in timber member  $i$ ;
- $d$  is the fastener diameter;
- $M_{y,Rk}$  is the characteristic fastener yield moment;
- $\beta$  is the ratio between the embedment strength of the members;
- $F_{ax,Rk}$  is the characteristic axial withdrawal capacity of the fastener, see (2).

NOTE: Plasticity of joints can be assured when relatively slender fasteners are used. In that case, failure modes (f) and (k) are governing.

(2) In the expressions (8.6) and (8.7), the first term on the right hand side is the load-carrying capacity according to the Johansen yield theory, whilst the second term  $F_{ax,Rk}/4$  is the contribution from the rope effect. The contribution to the load-carrying capacity due to the rope effect should be limited to following percentages of the Johansen part:

- Round nails 15 %
- Square and grooved nails 25 %
- Other nails 50 %
- Screws 100%
- Bolts 25 %
- Dowels 0 %

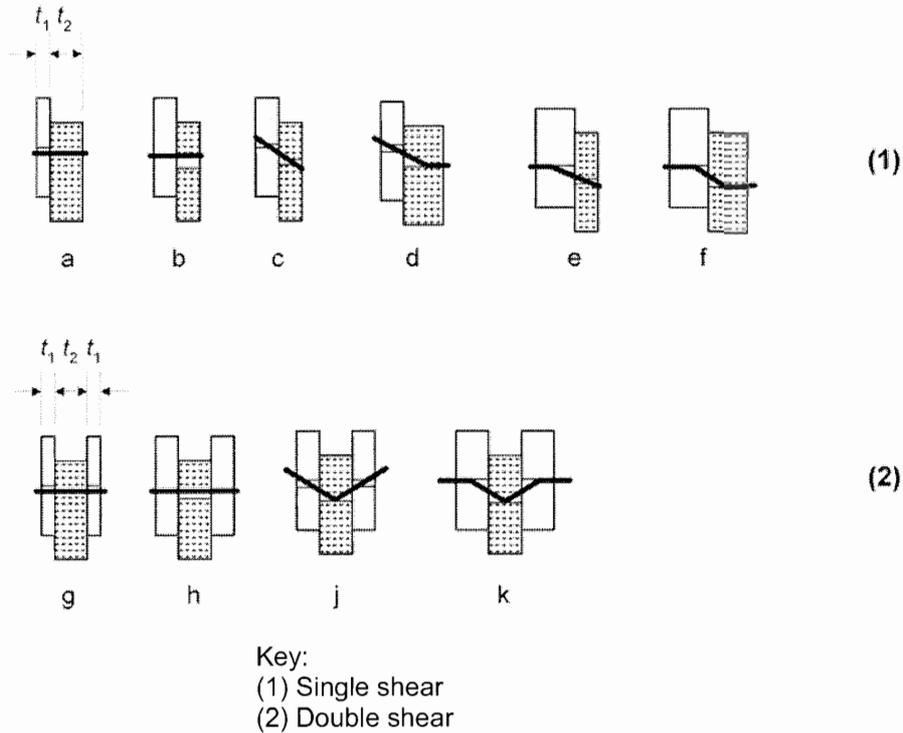
If  $F_{ax,Rk}$  is not known then the contribution from the rope effect should be taken as zero.

For single shear fasteners the characteristic withdrawal capacity,  $F_{ax,Rk}$ , is taken as the lower of the capacities in the two members. The different modes of failure are illustrated in Figure 8.2. For the withdrawal capacity,  $F_{ax,Rk}$ , of bolts the resistance provided by the washers may be taken into account, see 8.5.2(2).

(3) If no design rules are given below, the characteristic embedment strength  $f_{h,k}$  should be determined according to EN 383 and EN 14358.

(4) If no design rules are given below, the characteristic yield moment  $M_{y,Rk}$  should be determined

according to EN 409 and EN 14358.



NOTE: The letters correspond to the references of the expressions (8.6) and (8.7)

Figure 8.2 – Failure modes for timber and panel connections.

### 8.2.3 Steel-to-timber connections

(1) The characteristic load-carrying capacity of a steel-to-timber connection depends on the thickness of the steel plates. Steel plates of thickness less than or equal to  $0,5d$  are classified as thin plates and steel plates of thickness greater than or equal to  $d$  with the tolerance on hole diameters being less than  $0,1d$  are classified as thick plates. The characteristic load-carrying capacity of connections with steel plate thickness between a thin and a thick plate should be calculated by linear interpolation between the limiting thin and thick plate values.

(2)P The strength of the steel plate shall be checked.

(3) The characteristic load-carrying capacity for nails, bolts, dowels and screws per shear plane per fastener should be taken as the minimum value found from the following expressions:

– For a thin steel plate in single shear:

$$F_{v,Rk} = \min \left\{ \begin{array}{l} 0,4 f_{h,k} t_1 d \quad (a) \\ 1,15 \sqrt{2 M_{y,Rk} f_{h,k} d} + \frac{F_{ix,Rk}}{4} \quad (b) \end{array} \right. \quad (8.9)$$

– For a thick steel plate in single shear:

$$F_{v,Rk} = \min \begin{cases} f_{h,k} t_1 d & \text{(c)} \\ f_{h,k} t_1 d \left[ \sqrt{2 + \frac{4M_{y,Rk}}{f_{h,k} d t_1^2}} - 1 \right] + \frac{F_{ax,Rk}}{4} & \text{(d)} \\ 2,3 \sqrt{M_{y,Rk} f_{h,k} d} + \frac{F_{ax,Rk}}{4} & \text{(e) } \boxed{A1} \end{cases} \quad (8.10)$$

– For a steel plate of any thickness as the central member of a double shear connection:

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k} t_1 d & \text{(f)} \\ f_{h,1,k} t_1 d \left[ \sqrt{2 + \frac{4M_{y,Rk}}{f_{h,1,k} d t_1^2}} - 1 \right] + \frac{F_{ax,Rk}}{4} & \text{(g)} \\ 2,3 \sqrt{M_{y,Rk} f_{h,1,k} d} + \frac{F_{ax,Rk}}{4} & \text{(h)} \end{cases} \quad (8.11)$$

– For thin steel plates as the outer members of a double shear connection:

$$F_{v,Rk} = \min \begin{cases} 0,5 f_{h,2,k} t_2 d & \text{(j)} \\ 1,15 \sqrt{2 M_{y,Rk} f_{h,2,k} d} + \frac{F_{ax,Rk}}{4} & \text{(k)} \end{cases} \quad (8.12)$$

– For thick steel plates as the outer members of a double shear connection:

$$F_{v,Rk} = \min \begin{cases} 0,5 f_{h,2,k} t_2 d & \text{(l)} \\ 2,3 \sqrt{M_{y,Rk} f_{h,2,k} d} + \frac{F_{ax,Rk}}{4} & \text{(m)} \end{cases} \quad (8.13)$$

where:

- $F_{v,Rk}$  is the characteristic load-carrying capacity per shear plane per fastener;
- $f_{h,k}$  is the characteristic embedment strength in the timber member;
- $t_1$  is the smaller of the thickness of the timber side member or the penetration depth;
- $t_2$  is the thickness of the timber middle member;
- $d$  is the fastener diameter;
- $M_{y,Rk}$  is the characteristic fastener yield moment;
- $F_{ax,Rk}$  is the characteristic withdrawal capacity of the fastener.

NOTE 1: The different failure modes are illustrated in Figure 8.3

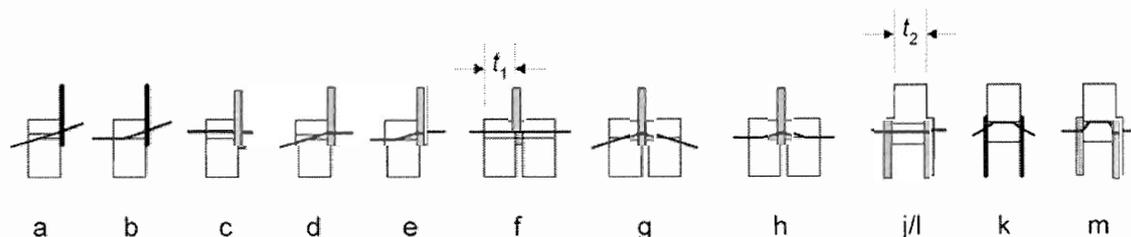


Figure 8.3 – Failure modes for steel-to-timber connections

(4) For the limitation of the rope effect  $F_{ax,Rk}$  8.2.2(2) applies.

(5)P It shall be taken into account that the load-carrying capacity of steel-to-timber connections with a loaded end may be reduced by failure along the perimeter of the fastener group.

NOTE: A method of determining the strength of the fastener group is given in Annex A (informative).

### 8.3 Nailed connections

#### 8.3.1 Laterally loaded nails

##### 8.3.1.1 General

(1) The symbols for the thicknesses in single and double shear connections (see Figure 8.4) are defined as follows:

$t_1$  is:

the headside thickness in a single shear connection;

the minimum of the head side timber thickness and the pointside penetration in a double shear connection;

$t_2$  is:

the pointside penetration in a single shear connection;

the central member thickness in a double shear connection.

**A1** (2) Timber should be pre-drilled when:

- the characteristic density of the timber is greater than 500 kg/m<sup>3</sup>;
- the diameter  $d$  of the nail exceeds 6 mm. **A1**

(3) For square and grooved nails, the nail diameter  $d$  should be taken as the side dimension.

(4) For smooth nails produced from wire with a minimum tensile strength of 600 N/mm<sup>2</sup>, the following characteristic values for yield moment should be used:

$$M_{y,Rk} = \begin{cases} 0,3 f_u d^{2,6} & \text{for round nails} \\ 0,45 f_u d^{2,6} & \text{for square and grooved nails} \end{cases} \quad (8.14)$$

where:

$M_{y,Rk}$  is the characteristic value for the yield moment, in Nmm;

$d$  is the nail diameter as defined in EN 14592, in mm;

$f_u$  is the tensile strength of the wire, in N/mm<sup>2</sup>.

(5) For nails with diameters up to 8 mm, the following characteristic embedment strengths in timber and LVL apply:

- without predrilled holes

$$f_{h,k} = 0,082 \rho_k d^{-0,3} \quad \text{N/mm}^2 \quad (8.15)$$

- with predrilled holes

$$f_{h,k} = 0,082 (1 - 0,01 d) \rho_k \quad \text{N/mm}^2 \quad (8.16)$$

where:

$\rho_k$  is the characteristic timber density, in kg/m<sup>3</sup>;

$d$  is the nail diameter, in mm.

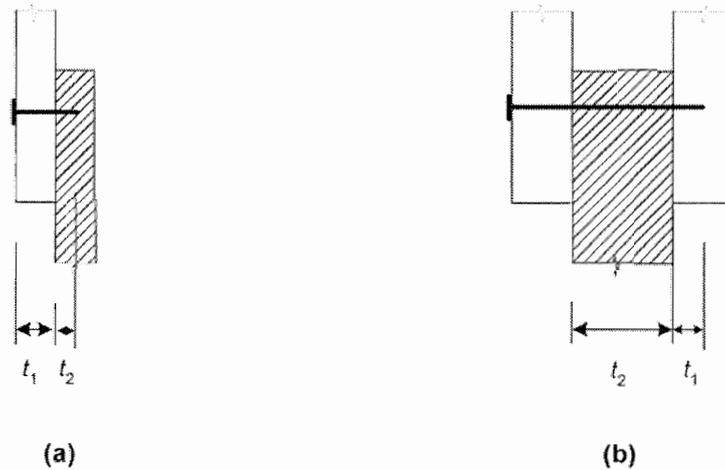


Figure 8.4 – Definitions of  $t_1$  and  $t_2$  (a) single shear connection, (b) double shear connection

(6) For nails with diameters greater than 8 mm the characteristic embedment strength values for bolts according to 8.5.1 apply.

(7) In a three-member connection, nails may overlap in the central member provided  $(t - t_2)$  is greater than  $4d$  (see Figure 8.5).

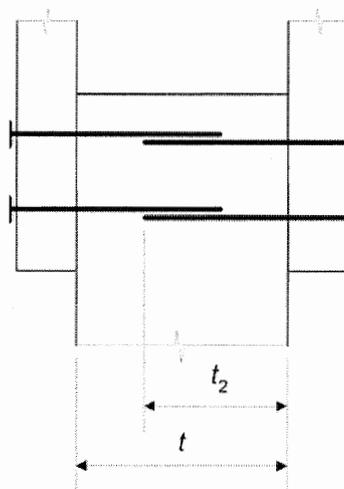


Figure 8.5 – Overlapping nails

(8) For one row of  $n$  nails parallel to the grain, unless the nails of that row are staggered perpendicular to grain by at least  $1d$  (see figure 8.6), the load-carrying capacity parallel to the grain (see 8.1.2(4)) should be calculated using the effective number of fasteners  $n_{ef}$ , where:

$$n_{ef} = n^{k_{ef}} \quad (8.17)$$

where:

$n_{ef}$  is the effective number of nails in the row;

$n$  is the number of nails in a row;  
 $k_{ef}$  is given in Table 8.1.

Table 8.1 – Values of  $k_{ef}$

Spacing <sup>a</sup>	$k_{ef}$	
	Not predrilled	Predrilled
$a_1 \geq 14d$	1,0	1,0
$a_1 = 10d$	0,85	0,85
$a_1 = 7d$	0,7	0,7
$a_1 = 4d$	-	0,5

<sup>a</sup> For intermediate spacings, linear interpolation of  $k_{ef}$  is permitted

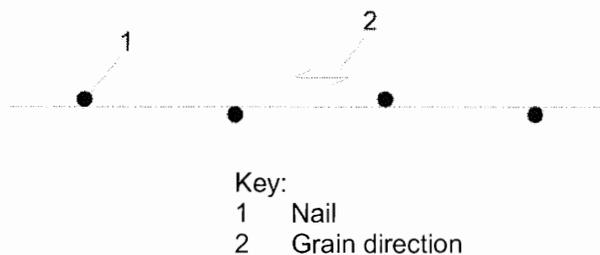


Figure 8.6 – Nails in a row parallel to grain staggered perpendicular to grain by  $d$

- (9) There should be at least two nails in a connection.  
(10) Requirements for structural detailing and control of nailed connections are given in 10.4.2.

### 8.3.1.2 Nailed timber-to-timber connections

- (1) For smooth nails the pointside penetration length should be at least  $8d$ .  
(2) For nails other than smooth nails, as defined in EN 14592, the pointside penetration length should be at least  $6d$ .  
(3) Nails in end grain should not be considered capable of transmitting lateral forces.  
(4) As an alternative to 8.3.1.2(3), for nails in end grain the following rules apply:
- In secondary structures smooth nails may be used. The design values of the load-carrying capacity should be taken as 1/3 of the values for nails installed at right angles to the grain;
  - Nails other than smooth nails, as defined in EN 14592, may be used in structures other than secondary structures. The design values of the load-carrying capacity should be taken as 1/3 of the values for smooth nails of equivalent diameter installed at right angles to the grain, provided that:
    - the nails are only laterally loaded;
    - there are at least three nails per connection;
    - the pointside penetration is at least  $10d$ ;
    - the connection is not exposed to service class 3 conditions;
    - the prescribed spacings and edge distances given in Table 8.2 are satisfied.

Note 1: An example of a secondary structure is a fascia board nailed to rafters.

Note 2: The recommended application rule is given in 8.3.1.2(3). The National choice may be specified in the National annex.

(5) Minimum spacings and edge and end distances are given in Table 8.2, where (see Figure 8.7):

- $a_1$  is the spacing of nails within one row parallel to grain;
- $a_2$  is the spacing of rows of nails perpendicular to grain;
- $a_{3,c}$  is the distance between nail and unloaded end;
- $a_{3,t}$  is the distance between nail and loaded end;
- $a_{4,c}$  is the distance between nail and unloaded edge;
- $a_{4,t}$  is the distance between nail and loaded edge;
- $\alpha$  is the angle between the force and the grain direction.

**Table 8.2 – Minimum spacings and edge and end distances for nails**

Spacing or distance (see Figure 8.7)	Angle $\alpha$	Minimum spacing or end/edge distance		
		without predrilled holes		with predrilled holes
		$\rho_k \leq 420 \text{ kg/m}^3$	$420 \text{ kg/m}^3 < \rho_k \leq 500 \text{ kg/m}^3$	
Spacing $a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$d < 5 \text{ mm}$ : $(5+5 \cos \alpha ) d$ $d \geq 5 \text{ mm}$ : $(5+7 \cos \alpha ) d$	$(7+8 \cos \alpha ) d$	$(4+ \cos \alpha ) d$
Spacing $a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$(3+ \sin \alpha ) d$
Distance $a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$(10+5 \cos \alpha) d$	$(15+5 \cos \alpha) d$	$(7+5 \cos \alpha) d$
Distance $a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha \leq 270^\circ$	$10d$	$15d$	$7d$
Distance $a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$d < 5 \text{ mm}$ : $(5+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$ : $(5+5 \sin \alpha) d$	$d < 5 \text{ mm}$ : $(7+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$ : $(7+5 \sin \alpha) d$	$d < 5 \text{ mm}$ : $(3+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$ : $(3+4 \sin \alpha) d$
Distance $a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$3d$

(6) Timber should be pre-drilled when the thickness of the timber members is smaller than

$$t = \max \left\{ \begin{array}{l} 7d \\ (13d - 30) \frac{\rho_k}{400} \end{array} \right. \quad (8.18)$$

where:

$t$  is the minimum thickness of timber member to avoid pre-drilling, in mm;

$\rho_k$  is the characteristic timber density in kg/m<sup>3</sup>;  
 $d$  is the nail diameter, in mm.

(7) Timber of species especially sensitive to splitting should be pre-drilled when the thickness of the timber members is smaller than

$$t = \max \left\{ \begin{array}{l} 14d \\ (13d - 30) \frac{\rho_k}{200} \end{array} \right. \quad (8.19)$$

Expression (8.19) may be replaced by expression (8.18) for edge distances given by:

$$a_4 \geq 10 d \quad \text{for } \rho_k \leq 420 \text{ kg/m}^3$$

$$a_4 \geq 14 d \quad \text{for } 420 \text{ kg/m}^3 \leq \rho_k \leq 500 \text{ kg/m}^3.$$

Note: Examples of species sensitive to splitting are fir (*abies alba*), Douglas fir (*pseudotsuga menziesii*) and spruce (*picea abies*). It is recommended to apply 8.3.1.2(7) for species fir (*abies alba*) and Douglas fir (*pseudotsuga menziesii*). The National choice may be specified in the National annex.

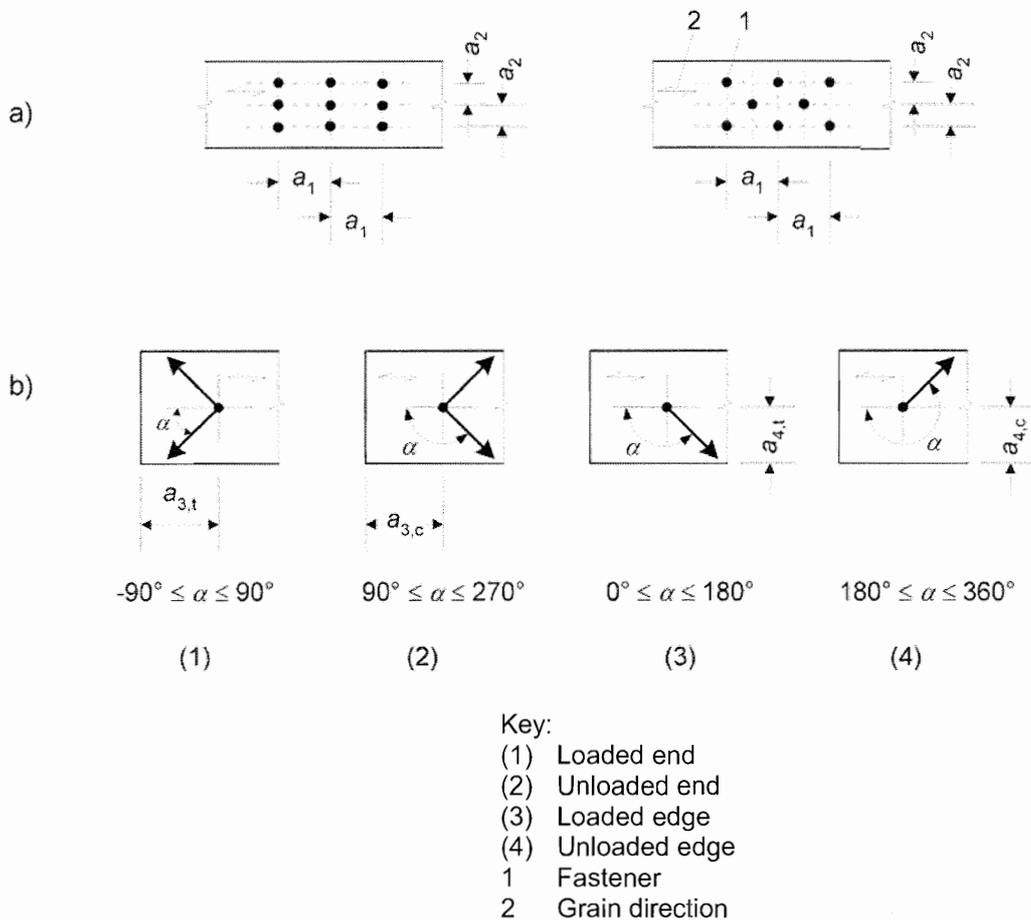


Figure 8.7 – Spacings and end and edge distances  
(a) Spacing parallel to grain in a row and perpendicular to grain between rows, (b) Edge and end distances

### 8.3.1.3 Nailed panel-to-timber connections

(1) Minimum nail spacings for all nailed panel-to-timber connections are those given in Table 8.2, multiplied by a factor of 0,85. The end/edge distances for nails remain unchanged unless otherwise stated below.

(2) Minimum edge and end distances in plywood members should be taken as  $3d$  for an unloaded edge (or end) and  $(3 + 4 \sin \alpha)d$  for a loaded edge (or end), where  $\alpha$  is the angle between the direction of the load and the loaded edge (or end).

(3) For nails with a head diameter of at least  $2d$ , the characteristic embedment strengths are as follows:

– for plywood:

$$f_{h,k} = 0,11 \rho_k d^{-0,3} \quad (8.20)$$

where:

$f_{h,k}$  is the characteristic embedment strength, in  $\text{N/mm}^2$ ;

$\rho_k$  is the characteristic plywood density in  $\text{kg/m}^3$ ;

$d$  is the nail diameter, in mm;

– for hardboard in accordance with EN 622-2:

$$f_{h,k} = 30 d^{-0,3} t^{0,6} \quad (8.21)$$

where:

$f_{h,k}$  is the characteristic embedment strength, in  $\text{N/mm}^2$ ;

$d$  is the nail diameter, in mm;

$t$  is the panel thickness, in mm.

– for particleboard and OSB:

$$f_{h,k} = 65 d^{-0,7} t^{0,1} \quad (8.22)$$

where:

$f_{h,k}$  is the characteristic embedment strength, in  $\text{N/mm}^2$ ;

$d$  is the nail diameter, in mm;

$t$  is the panel thickness, in mm.

### 8.3.1.4 Nailed steel-to-timber connections

(1) The minimum edge and end distances for nails given in Table 8.2 apply. Minimum nail spacings are those given in Table 8.2, multiplied by a factor of 0,7.

### 8.3.2 Axially loaded nails

**A1** (1)P Nails used to resist permanent or long-term axial loading shall be threaded.

NOTE: The following definition of threaded nails is given in EN 14592: Nail that has its shank profiled or deformed over a part of its length of minimum  $4,5 d$  ( $4,5$  times the nominal diameter) and that has a characteristic withdrawal parameter  $f_{ax,k}$  greater than or equal to  $6 \text{ N/mm}^2$  when measured on timber with a characteristic density of  $350 \text{ kg/m}^3$  when conditioned to constant mass at  $20 \text{ }^\circ\text{C}$  and  $65 \%$  relative humidity. **A1**

(2) For threaded nails, only the threaded part should be considered capable of transmitting axial load.

(3) Nails in end grain should be considered incapable of transmitting axial load.

(4) The characteristic withdrawal capacity of nails,  $F_{ax,Rk}$ , for nailing perpendicular to the grain (Figure 8.8 (a) and for slant nailing (Figure 8.8 (b)), should be taken as the smaller of the values

found from the following expressions:

– For nails other than smooth nails, as defined in EN 14592:

$$F_{ax,Rk} = \begin{cases} f_{ax,k} d t_{pen} & \text{(a)} \\ f_{head,k} d_h^2 & \text{(b)} \end{cases} \quad (8.23)$$

– For smooth nails:

$$F_{ax,Rk} = \begin{cases} f_{ax,k} d t_{pen} & \text{(a)} \\ f_{ax,k} d t + f_{head,k} d_h^2 & \text{(b)} \end{cases} \quad (8.24)$$

where:

- $f_{ax,k}$  is the characteristic pointside withdrawal strength;
- $f_{head,k}$  is the characteristic headside pull-through strength;
- $d$  is the nail diameter according to 8.3.1.1;
- $t_{pen}$  is the pointside penetration length or the length of the threaded part in the pointside member;
- $t$  is the thickness of the headside member;
- $d_h$  is the nail head diameter.

(5) The characteristic strengths  $f_{ax,k}$  and  $f_{head,k}$  should be determined by tests in accordance with EN 1382, EN 1383 and EN 14358 unless specified in the following.

(6) For smooth nails with a pointside penetration of at least  $12d$ , the characteristic values of the withdrawal and pull-through strengths should be found from the following expressions:

$$f_{ax,k} = 20 \times 10^{-6} \rho_k^2 \quad (8.25)$$

$$f_{head,k} = 70 \times 10^{-6} \rho_k^2 \quad (8.26)$$

where:

$\rho_k$  is the characteristic timber density in  $\text{kg/m}^3$ ;

(7) For smooth nails, the pointside penetration  $t_{pen}$  should be at least  $8d$ . For nails with a pointside penetration smaller than  $12d$  the withdrawal capacity should be multiplied by  $(t_{pen}/4d - 2)$ . For threaded nails, the pointside penetration should be at least  $6d$ . For nails with a pointside penetration smaller than  $8d$  the withdrawal capacity should be multiplied by  $(t_{pen}/2d - 3)$ .

(8) For structural timber which is installed at or near fibre saturation point, and which is likely to dry out under load, the values of  $f_{ax,k}$  and  $f_{head,k}$  should be multiplied by  $2/3$ .

(9) The spacings, end and edge distances for laterally loaded nails apply to axially loaded nails.

(10) For slant nailing the distance to the loaded end should be at least  $10d$  (see Figure 8.8(b)). There should be at least two slant nails in a connection. **A1**

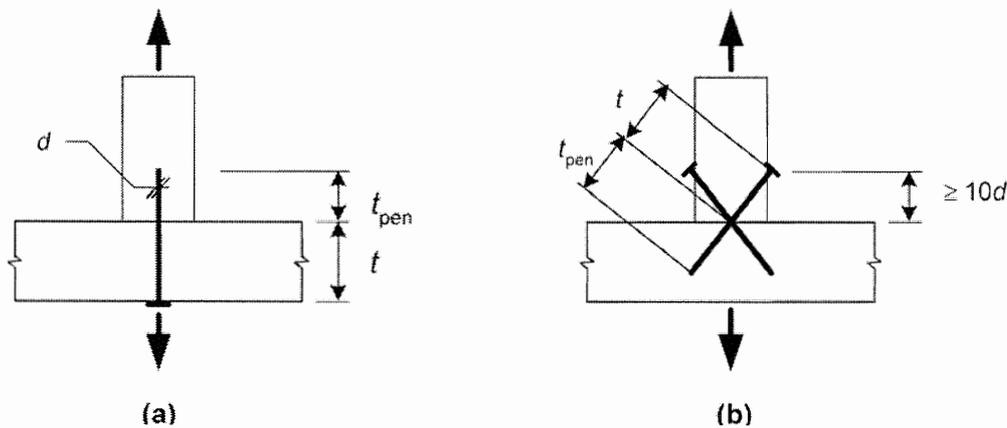


Figure 8.8 – (a) Nailing perpendicular to grain and (b) slant nailing

### 8.3.3 Combined laterally and axially loaded nails

(1) For connections subjected to a combination of axial load ( $F_{ax,Ed}$ ) and lateral load ( $F_{v,Ed}$ ) the following expressions should be satisfied:

– for smooth nails:

$$\frac{F_{ax,Ed}}{F_{ax,Rd}} + \frac{F_{v,Ed}}{F_{v,Rd}} \leq 1 \quad (8.27)$$

– for nails other than smooth nails, as defined in EN 14592:

$$\left( \frac{F_{ax,Ed}}{F_{ax,Rd}} \right)^2 + \left( \frac{F_{v,Ed}}{F_{v,Rd}} \right)^2 \leq 1 \quad (8.28)$$

where:

$F_{ax,Rd}$  and  $F_{v,Rd}$  are the design load-carrying capacities of the connection loaded with axial load or lateral load respectively.

### 8.4 Stapled connections

**[A1]** (1) The rules given in 8.3, except for 8.3.1.1(4) and (6) and 8.3.1.2(7), apply for round or nearly round or rectangular staples with bevelled or symmetrical pointed legs. **[A1]**

(2) For staples with rectangular cross-sections the diameter  $d$  should be taken as the square root of the product of both dimensions.

(3) The width  $b$  of the staple crown should be at least  $6d$ , and the pointside penetration length  $t_2$  should be at least  $14d$ , see Figure 8.9.

(4) There should be at least two staples in a connection.

(5) The lateral design load-carrying capacity per staple per shear plane should be considered as equivalent to that of two nails with the staple diameter, provided that the angle between the crown and the direction of the grain of the timber under the crown is greater than  $30^\circ$ , see Figure 8.10. If the angle between the crown and the direction of the grain under the crown is equal to or less than  $30^\circ$ , then the lateral design load-carrying capacity should be multiplied by a factor of 0,7.

(6) For staples produced from wire with a minimum tensile strength of  $800 \text{ N/mm}^2$ , the following characteristic yield moment per leg should be used:

$$M_{y,Rk} = 240 d^{2.6} \quad (8.29)$$

where:

$M_{y,Rk}$  is the characteristic yield moment, in Nmm;

$d$  is the staple leg diameter, in mm.

(7) For a row of  $n$  staples parallel to the grain, the load-carrying capacity in that direction should be calculated using the effective number of fasteners  $n_{ef}$  according to 8.3.1.1(8)

(8) Minimum staple spacings, edge and end distances are given in Table 8.3, and illustrated in Figure 8.10 where  $\theta$  is the angle between the staple crown and the grain direction.

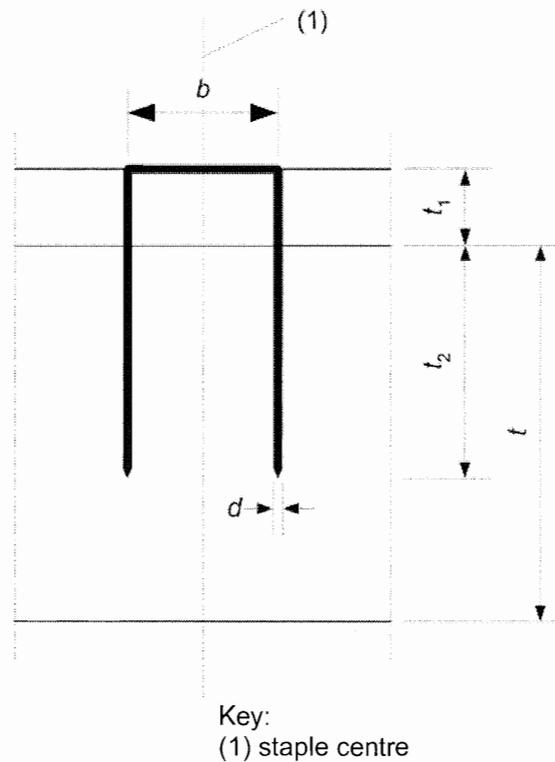


Figure 8.9 – Staple dimensions

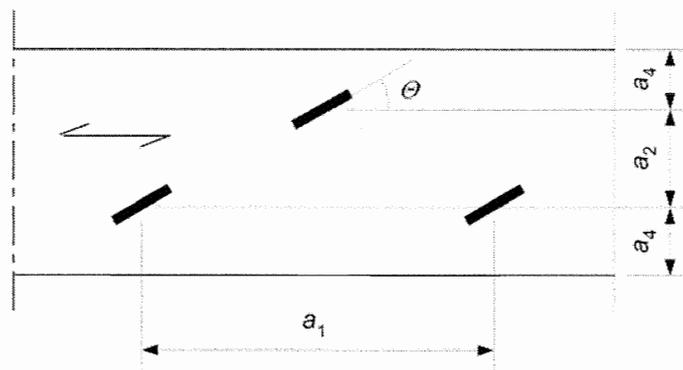


Figure 8.10 – Definition of spacing for staples

Table 8.3 – Minimum spacings and edge and end distances for staples

Spacing and edge/end distances (see Figure 8.7)	Angle	Minimum spacing or edge/end distance
$a_1$ (parallel to grain) for $\theta \geq 30^\circ$ for $\theta < 30^\circ$	$0^\circ \leq \alpha \leq 360^\circ$	$(10 + 5  \cos \alpha ) d$ $(15 + 5  \cos \alpha ) d$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$15 d$
$a_{3,i}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$(15 + 5  \cos \alpha ) d$
$a_{3,e}$ (unloaded end)	$90^\circ \leq \alpha \leq 270^\circ$	$15 d$
$a_{4,i}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$(15 + 5  \sin \alpha ) d$
$a_{4,e}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$10 d$

## 8.5 Bolted connections

### 8.5.1 Laterally loaded bolts

#### 8.5.1.1 General and bolted timber-to-timber connections

(1) For bolts the following characteristic value for the yield moment should be used:

$$M_{y,Rk} = 0,3 f_{u,k} d^{2,6} \quad (8.30)$$

where:

$M_{y,Rk}$  is the characteristic value for the yield moment, in Nmm;

$f_{u,k}$  is the characteristic tensile strength, in N/mm<sup>2</sup>;

$d$  is the bolt diameter, in mm.

(2) For bolts up to 30 mm diameter, the following characteristic embedment strength values in timber and LVL should be used, at an angle  $\alpha$  to the grain:

$$f_{h,a,k} = \frac{f_{h,0,k}}{k_{90} \sin^2 \alpha + \cos^2 \alpha} \quad (8.31)$$

$$f_{h,0,k} = 0,082 (1 - 0,01 d) \rho_k \quad (8.32)$$

where:

$$k_{90} = \begin{cases} 1,35 + 0,015 d & \text{for softwoods} \\ 1,30 + 0,015 d & \text{for LVL} \\ 0,90 + 0,015 d & \text{for hardwoods} \end{cases} \quad (8.33)$$

and:

$f_{h,0,k}$  is the characteristic embedment strength parallel to grain, in N/mm<sup>2</sup>;

$\rho_k$  is the characteristic timber density, in kg/m<sup>3</sup>;

$\alpha$  is the angle of the load to the grain;

$d$  is the bolt diameter, in mm.

(3) Minimum spacings and edge and end distances should be taken from Table 8.4, with symbols illustrated in Figure 8.7.

Table 8.4 – Minimum values of spacing and edge and end distances for bolts

Spacing and end/edge distances (see Figure 8.7)	Angle	Minimum spacing or distance
$a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(4 +  \cos \alpha ) d$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$4 d$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$\max(7 d; 80 \text{ mm})$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$	$\lceil A_1 \rceil (1 + 6 \sin \alpha) d$
	$150^\circ \leq \alpha < 210^\circ$	$4 d$
	$210^\circ \leq \alpha \leq 270^\circ$	$(1 + 6  \sin \alpha ) d \lceil A_1 \rceil$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$\max[(2 + 2 \sin \alpha) d; 3d]$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$3 d$

(4) For one row of  $n$  bolts parallel to the grain direction, the load-carrying capacity parallel to grain, see 8.1.2(4), should be calculated using the effective number of bolts  $n_{ef}$  where:

$$n_{ef} = \min \left\{ \begin{array}{l} n \\ n^{0,9} \sqrt[4]{\frac{a_1}{13d}} \end{array} \right. \quad (8.34)$$

where:

$a_1$  is the spacing between bolts in the grain direction;

$d$  is the bolt diameter

$n$  is the number of bolts in the row.

For loads perpendicular to grain, the effective number of fasteners should be taken as

$$n_{ef} = n \quad (8.35)$$

For angles  $0^\circ < \alpha < 90^\circ$  between load and grain direction,  $n_{ef}$  may be determined by linear interpolation between expressions (8.34) and (8.35).

(5) Requirements for minimum washer dimensions and thickness in relation to bolt diameter are given in 10.4.3

### 8.5.1.2 Bolted panel-to-timber connections

(1) For plywood the following embedment strength, in  $\text{N/mm}^2$ , should be used at all angles to the face grain:

$$f_{h,k} = 0,11 (1 - 0,01 d) \rho_k \quad (8.36)$$

where:

$\rho_k$  is the characteristic plywood density, in  $\text{kg/m}^3$ ;

$d$  is the bolt diameter, in mm.

(2) For particleboard and OSB the following embedment strength value, in  $\text{N/mm}^2$ , should be used at all angles to the face grain:

$$f_{h,k} = 50 d^{-0,6} t^{0,2} \quad (8.37)$$

where:

$d$  is the bolt diameter, in mm;

$t$  is the panel thickness, in mm.

### 8.5.1.3 Bolted steel-to-timber connections

(1) The rules given in 8.2.3 apply.

### 8.5.2 Axially loaded bolts

(1) The axial load-bearing capacity and withdrawal capacity of a bolt should be taken as the lower value of:

- the bolt tensile capacity;
- the load-bearing capacity of either the washer or (for steel-to-timber connections) the steel plate.

(2) The bearing capacity of a washer should be calculated assuming a characteristic compressive strength on the contact area of  $3,0f_{c,90,k}$ .

(3) The bearing capacity per bolt of a steel plate should not exceed that of a circular washer with a diameter which is the minimum of:

- $12t$ , where  $t$  is the plate thickness;
- $4d$ , where  $d$  is the bolt diameter.

### 8.6 Dowelled connections

(1) The rules given in 8.5.1 except 8.5.1.1(3) apply.

(2) The dowel diameter should be greater than 6 mm and less than 30 mm.

(3) Minimum spacing and edge and end distances are given in Table 8.5, with symbols illustrated in Figure 8.7.

**Table 8.5 – Minimum spacings and edge and end distances for dowels**

Spacing and edge/end distances (see Figure 8.7)	Angle	Minimum spacing or edge/end distance
$a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(3 + 2  \cos \alpha ) d$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$3 d$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$\max(7 d; 80 \text{ mm})$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$	$\max(a_{3,t}  \sin \alpha  d; 3d)$
	$150^\circ \leq \alpha < 210^\circ$	$3 d$
	$210^\circ \leq \alpha \leq 270^\circ$	$\max(a_{3,t}  \sin \alpha  d; 3d)$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$\max([2 + 2 \sin \alpha] d; 3d)$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$3 d$

(4) Requirements for dowel hole tolerances are given in 10.4.4.

## 8.7 Screwed connections

### 8.7.1 Laterally loaded screws

(1)P The effect of the threaded part of the screw shall be taken into account in determining the load-carrying capacity, by using an effective diameter  $d_{ef}$ .

(2) For smooth shank screws, where the outer thread diameter is equal to the shank diameter, the rules given in 8.2 apply, provided that:

- The effective diameter  $d_{ef}$  is taken as the smooth shank diameter;
- The smooth shank penetrates into the member containing the point of the screw by not less than  $4d$ .

(3) Where the conditions in (2) are not satisfied, the screw load-carrying capacity should be calculated using an effective diameter  $d_{ef}$  taken as 1,1 times the thread root diameter.

(4) For smooth shank screws with a diameter  $d > 6$  mm, the rules in 8.5.1 apply.

(5) For smooth shank screws with a diameter of 6 mm or less, the rules of 8.3.1 apply.

(6) Requirements for structural detailing and control of screwed joints are given in 10.4.5.

### 8.7.2 Axially loaded screws

**A1** (1)P For the verification of resistance of axially loaded screws, the following failure modes shall be taken into account:

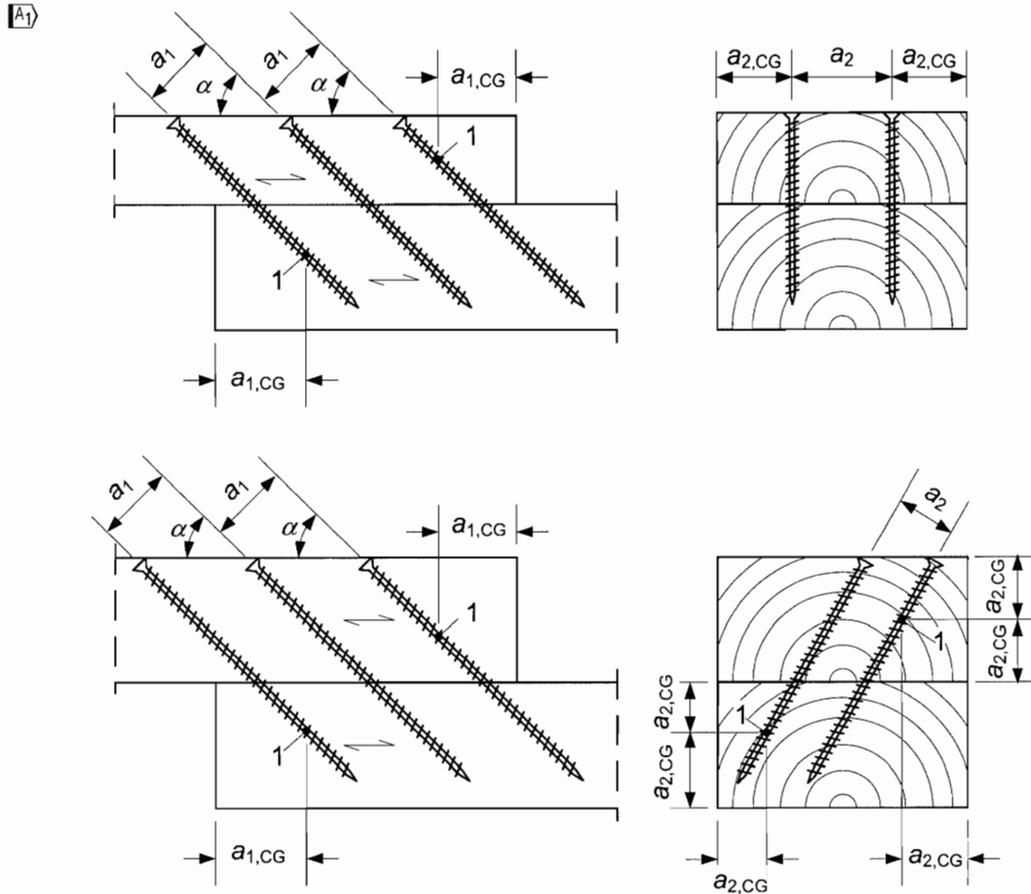
- the withdrawal failure of the threaded part of the screw;
- the tear-off failure of the screw head of screws used in combination with steel plates, the tear-off resistance of the screw head should be greater than the tensile strength of the screw;
- the pull-through failure of the screw head;
- the tensile failure of the screw;
- the buckling failure of the screw when loaded in compression;
- failure along the circumference of a group of screws used in conjunction with steel plates (block shear or plug shear);

(2) Minimum spacings and end and edge distances for axially loaded screws, see figure 8.11a, should be taken from Table 8.6, provided the timber thickness  $t \geq 12d$ .

**Table 8.6 – Minimum spacings and end and edge distances for axially loaded screws**

Minimum screw spacing in a plane parallel to the grain	Minimum screw spacing perpendicular to a plane parallel to the grain	Minimum end distance of the centre of gravity of the threaded part of the screw in the member	Minimum edge distance of the centre of gravity of the threaded part of the screw in the member
$a_1$	$a_2$	$a_{1,CG}$	$a_{2,CG}$
$7d$	$5d$	$10d$	$4d$

**A1**



Key: 1 Centre of gravity of the threaded part of the screw in the member

Figure 8.11.a – Spacings and end and edge distances

(3) The minimum point side penetration length of the threaded part should be  $6d$ .

(4) For connections with screws in accordance with EN 14592 with

–  $6 \text{ mm} \leq d \leq 12 \text{ mm}$

–  $0,6 \leq d_1/d \leq 0,75$

where

$d$  is the outer thread diameter;

$d_1$  is the inner thread diameter

the characteristic withdrawal capacity should be taken as:

$$F_{ax,k,Rk} = \frac{n_{ef} f_{ax,k} d \ell_{ef} k_d}{1,2 \cos^2 \alpha + \sin^2 \alpha} \quad (8.38)$$

where:

$$f_{ax,k} = 0,52 d^{-0,5} \ell_{ef}^{-0,1} \rho_k^{0,8} \quad (8.39)$$

$$k_d = \min \left\{ \begin{array}{l} \frac{d}{8} \\ 1 \end{array} \right. \quad (8.40) \quad \text{A1}$$

- Ⓐ)  $F_{ax,\alpha,Rk}$  is the characteristic withdrawal capacity of the connection at an angle  $\alpha$  to the grain, in N;  
 $f_{ax,k}$  is the characteristic withdrawal strength perpendicular to the grain, in N/mm<sup>2</sup>;  
 $n_{ef}$  is the effective number of screws, see 8.7.2(8);  
 $\ell_{ef}$  is the penetration length of the threaded part, in mm;  
 $\rho_k$  is the characteristic density, in kg/m<sup>3</sup>;  
 $\alpha$  is the angle between the screw axis and the grain direction, with  $\alpha \geq 30^\circ$ .

NOTE: Failure modes in the steel or in the timber around the screw are brittle, i.e. with small ultimate deformation and therefore have a limited possibility for stress redistribution.

(5) Where the requirements with respect to the outer and inner thread diameter given in (4) are not satisfied, the characteristic withdrawal capacity,  $F_{ax,\alpha,Rk}$ , should be taken as:

$$F_{ax,\alpha,Rk} = \frac{n_{ef} f_{ax,k} d \ell_{ef}}{1,2 \cos^2 \alpha + \sin^2 \alpha} \left( \frac{\rho_k}{\rho_a} \right)^{0,8} \quad (8.40a)$$

where

$f_{ax,k}$  is the characteristic withdrawal parameter perpendicular to the grain determined in accordance with EN 14592 for the associated density  $\rho_a$ ;

$\rho_a$  is the associated density for  $f_{ax,k}$ , in kg/m<sup>3</sup>

and the other symbols are explained in (4).

(6) The characteristic pull-through resistance of connections with axially loaded screws should be taken as:

$$F_{ax,\alpha,Rk} = n_{ef} f_{head,k} d_h^2 \left( \frac{\rho_k}{\rho_a} \right)^{0,8} \quad (8.40b)$$

where:

$F_{ax,\alpha,Rk}$  is the characteristic pull-through capacity of the connection at an angle  $\alpha$  to the grain in N, with  $\alpha \geq 30^\circ$ ;

$f_{head,k}$  is the characteristic pull-through parameter of the screw determined in accordance with EN 14592 for the associated density  $\rho_a$ ;

$d_h$  is the diameter of the screw head in mm

and the other symbols are explained in (4).

(7) The characteristic tensile resistance of the connection (head tear-off or tensile capacity of shank),  $F_{t,Rk}$ , should be taken as:

$$F_{t,Rk} = n_{ef} f_{tens,k} \quad (8.40c)$$

where

$f_{tens,k}$  is the characteristic tensile capacity of the screw determined in accordance with EN 14592;

$n_{ef}$  is the effective number of screws, see 8.7.2(8).

(8) For a connection with a group of screws loaded by a force component parallel to the shank, the effective number of screws is given by:

$$n_{ef} = n^{0,9} \quad (8.41) \quad \text{Ⓐ}$$

$\boxed{A_1}$  where:

$n_{ef}$  is the effective number of screws;

$n$  is the number of screws acting together in a connection.  $\boxed{A_1}$

### 8.7.3 Combined laterally and axially loaded screws

(1) For screwed connections subjected to a combination of axial load and lateral load, expression (8.28) should be satisfied.

## 8.8 Connections made with punched metal plate fasteners

### 8.8.1 General

(1)P Connections made with punched metal plate fasteners shall comprise punched metal plate fasteners of the same type, size and orientation, placed on each side of the timber members.

(2) The following rules apply only to punched metal plate fasteners with two orthogonal directions.

### 8.8.2 Plate geometry

(1) The symbols used to define the geometry of a punched metal plate fastener joint are given in Figure 8.11 and defined as follows:

x-direction main direction of plate;

y-direction perpendicular to the main plate direction;

$\alpha$  angle between the x-direction and the force (tension:  $0^\circ \leq \gamma < 90^\circ$ , compression:  $90^\circ \leq \gamma < 180^\circ$ );

$\beta$  angle between the grain-direction and the force;

$\gamma$  angle between the x-direction and the connection line;

$A_{ef}$  area of the total contact surface between the plate and the timber, reduced by 5 mm from the edges of the timber and by a distance in the grain direction from the end of timber equal to 6 times the fastener's nominal thickness;

$l$  dimension of the plate measured along the connection line.

### 8.8.3 Plate strength properties

(1)P The plate shall have characteristic values for the following properties, determined in accordance with EN 14545 from tests carried out in accordance with EN 1075:

$f_{a,0,0}$  the anchorage capacity per unit area for  $\alpha = 0^\circ$  and  $\beta = 0^\circ$ ;

$f_{a,90,90}$  the anchorage capacity per unit area for  $\alpha = 90^\circ$  and  $\beta = 90^\circ$ ;

$f_{t,0}$  the tension capacity per unit width of plate for  $\alpha = 0^\circ$ ;

$f_{c,0}$  the compression capacity per unit width of plate for  $\alpha = 0^\circ$ ;

$f_{v,0}$  the shear capacity per unit width of plate in the x-direction;

$f_{t,90}$  the tension capacity per unit width of plate for  $\alpha = 90^\circ$ ;

$f_{c,90}$  the compression capacity per unit width of plate for  $\alpha = 90^\circ$ ;

$f_{v,90}$  the shear capacity per unit width of plate in the y-direction;

$k_1, k_2, \alpha_0$  constants.

(2)P In order to calculate the design tension, compression and shear capacities of the plate the value of  $k_{mod}$  shall be taken as 1,0.

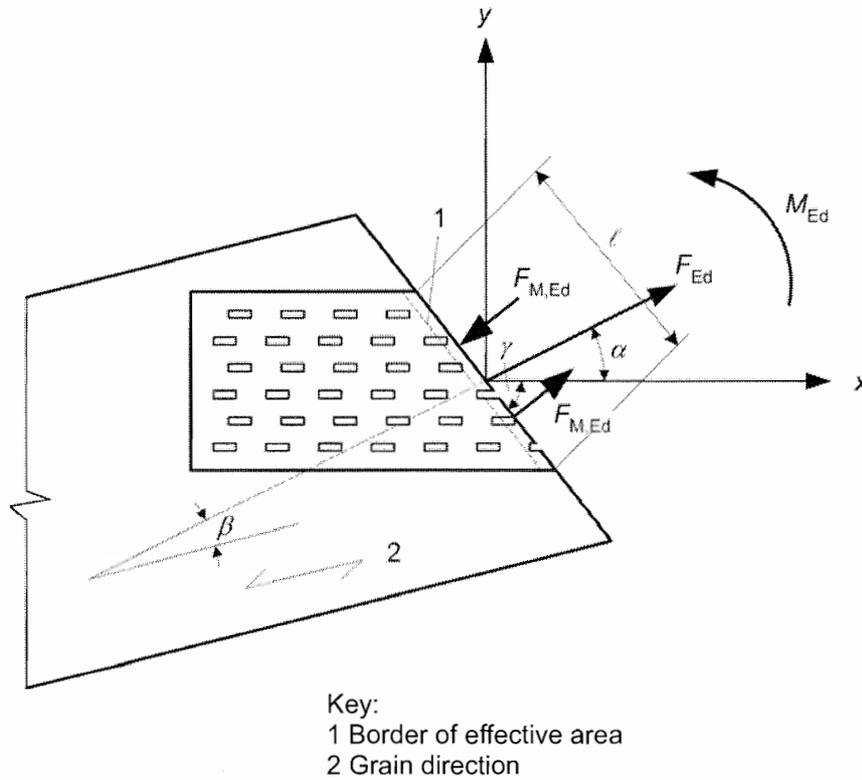


Figure 8.11 – Geometry of punched metal plate connection loaded by a force  $F_{Ed}$  and moment  $M_{Ed}$

#### 8.8.4 Plate anchorage strengths

(1) The characteristic anchorage strength per plate  $f_{a,\alpha,\beta,k}$  should either be derived from tests or calculated from:

$$f_{a,\alpha,\beta,k} = \max \begin{cases} f_{a,\alpha,0,k} - (f_{a,\alpha,0,k} - f_{a,90,90,k}) \frac{\beta}{45^\circ} & \text{for } \beta \leq 45^\circ, \text{ or} \\ f_{a,0,0,k} - (f_{a,0,0,k} - f_{a,90,90,k}) \sin(\max(\alpha, \beta)) & \end{cases} \quad (8.42)$$

$$f_{a,\alpha,\beta,k} = f_{a,0,0,k} - (f_{a,0,0,k} - f_{a,90,90,k}) \sin(\max(\alpha, \beta)) \quad \text{for } 45^\circ < \beta \leq 90^\circ \quad (8.43)$$

(2) The characteristic anchorage strength per plate parallel to grain should be taken as:

$$f_{a,\alpha,0,k} = \begin{cases} f_{a,0,0,k} + k_1 \alpha & \text{when } \alpha \leq \alpha_0 \\ f_{a,0,0,k} + k_1 \alpha_0 + k_2 (\alpha - \alpha_0) & \text{when } \alpha_0 < \alpha \leq 90^\circ \end{cases} \quad (8.44)$$

The constants  $k_1$ ,  $k_2$  and  $\alpha_0$  should be determined from anchorage tests in accordance with EN 1075 and derived in accordance with the procedure given in EN 14545 for the actual plate type.

#### 8.8.5 Connection strength verification

##### 8.8.5.1 Plate anchorage capacity

(1) The design anchorage stress  $\tau_{F,d}$  on a single punched metal plate fastener imposed by a

force  $F_{Ed}$  and the design anchorage stress  $\tau_{M,d}$  imposed from a moment  $M_{Ed}$ , should be taken as:

$$\tau_{F,d} = \frac{F_{A,Ed}}{A_{ef}} \quad (8.45)$$

$$\tau_{M,d} = \frac{M_{A,Ed}}{W_p} \quad (8.46)$$

with:

$$W_p = \int_{A_{ef}} r dA \quad (8.47)$$

where:

$F_{A,Ed}$  is the design force acting on a single plate at the centroid of the effective area (i.e. half of the total force in the timber member);

$M_{A,Ed}$  is the design moment acting on a single plate on the centroid of the effective area;

$dA$  is the segmental area of the punched metal plate fastener;

$r$  is the distance from the centre of gravity of the plate to the segmental plate area  $dA$ ;

$A_{ef}$  is the effective plate area.

(2) As an alternative to expression (8.47),  $W_p$  may be conservatively approximated from:

$$W_p = \frac{A_{ef} d}{4} \quad (8.48)$$

with:

$$d = \sqrt{\left(\frac{A_{ef}}{h_{ef}}\right)^2 + h_{ef}^2} \quad (8.49)$$

where:

$h_{ef}$  is the maximum height of the effective anchorage area perpendicular to the longest side.

(3) Contact pressure between timber members may be taken into account to reduce the value of  $F_{Ed}$  in compression provided that the gap between the members has an average value, which is not greater than 1,5 mm, and a maximum value of 3 mm. In such cases the connection should be designed for a minimum compressive design force of  $F_{A,Ed}/2$ .

(4) Contact pressure between the timber members in chord splices in compression may be taken into account by designing the single plate for a design force,  $F_{A,Ed}$ , and a design moment  $M_{A,Ed}$ , according to the following expressions:

$$F_{A,Ed} = \sqrt{\left(\frac{F_{Ed} \cos \beta}{2} - \frac{3|M_{Ed}|}{2h}\right)^2 + (F_{Ed} \sin \beta)^2} \quad (8.50)$$

$$M_{A,Ed} = \frac{M_{Ed}}{2} \quad (8.51)$$

where:

$F_{Ed}$  is the design axial force of the chord acting on a single plate (compression or zero);

$M_{Ed}$  is the design moment of the chord acting on a single plate;

$h$  is the height of the chord.

(5) The following expression should be satisfied:

$$\left(\frac{\tau_{F,d}}{f_{a,\alpha,\beta,d}}\right)^2 + \left(\frac{\tau_{M,d}}{f_{a,0,0,d}}\right)^2 \leq 1 \quad (8.52)$$

### 8.8.5.2 Plate capacity

(1) For each joint interface, the forces in the two main directions should be taken as:

$$F_{x,Ed} = F_{Ed} \cos \alpha \pm 2F_{M,Ed} \sin \gamma \quad (8.53)$$

$$F_{y,Ed} = F_{Ed} \sin \alpha \pm 2F_{M,Ed} \cos \gamma \quad (8.54)$$

where:

$F_{Ed}$  is the design force in a single plate (i.e. half of the total force in the timber member)

$F_{M,Ed}$  is the design force from the moment on a single plate ( $F_{M,Ed} = 2 M_{Ed} / \ell$ )

(2) The following expression should be satisfied:

$$\left(\frac{F_{x,Ed}}{F_{x,Rd}}\right)^2 + \left(\frac{F_{y,Ed}}{F_{y,Rd}}\right)^2 \leq 1 \quad (8.55)$$

where:

$F_{x,Ed}$  and  $F_{y,Ed}$  are the design forces acting in the x and y direction,

$F_{x,Rd}$  and  $F_{y,Rd}$  are the corresponding design values of the plate capacity. They are determined from the maximum of the characteristic capacities at sections parallel or perpendicular to the main axes, based upon the following expressions for the characteristic plate capacities in these directions

$$F_{x,Rk} = \max \left\{ \begin{array}{l} |f_{n,0,k} \ell \sin(\gamma - \gamma_0 \sin(2\gamma))| \\ |f_{v,0,k} \ell \cos \gamma| \end{array} \right. \quad (8.56)$$

$$F_{y,Rk} = \max \left\{ \begin{array}{l} |f_{n,90,k} \ell \cos \gamma| \\ |k f_{v,90,k} \ell \sin \gamma| \end{array} \right. \quad (8.57)$$

with

$$f_{n,0,k} = \begin{cases} f_{t,0,k} & \text{for } F_{x,Ed} > 0 \\ f_{c,0,k} & \text{for } F_{x,Ed} \leq 0 \end{cases} \quad (8.58)$$

$$f_{n,90,k} = \begin{cases} f_{t,90,k} & \text{for } F_{y,Ed} > 0 \\ f_{c,90,k} & \text{for } F_{y,Ed} \leq 0 \end{cases} \quad (8.59)$$

$$k = \begin{cases} 1 + k_v \sin(2\gamma) & \text{for } F_{x,Ed} > 0 \\ 1 & \text{for } F_{x,Ed} \leq 0 \end{cases} \quad (8.60)$$

where  $\gamma_0$  and  $k_v$  are constants determined from shear tests in accordance with EN 1075 and derived in accordance with the procedure given in EN 14545 for the actual plate type.

(3) If the plate covers more than two connection lines on the member then the forces in each straight part of the connection line should be determined such that equilibrium is fulfilled and

that expression (8.55) is satisfied in each straight part of the connection line. All critical sections should be taken into account.

### 8.9 Split ring and shear plate connectors

(1) For connections made with ring connectors of type A or shear plate connectors of type B according to EN 912 and EN 14545, and with a diameter not bigger than 200 mm, the characteristic load-carrying capacity parallel to grain,  $F_{v,0,Rk}$  per connector and per shear plane should be taken as:

$$F_{v,0,Rk} = \min \begin{cases} k_1 k_2 k_3 k_4 (35 d_c^{1.5}) & \text{(a)} \\ k_1 k_3 h_e (31,5 d_c) & \text{(b)} \end{cases} \quad (8.61)$$

where:

$F_{v,0,Rk}$  is the characteristic load-carrying capacity parallel to the grain, in N;

$d_c$  is the connector diameter, in mm;

$h_e$  is the embedment depth, in mm;

$k_i$  are modification factors, with  $i = 1$  to 4, defined below.

(2) The minimum thickness of the outer timber members should be  $2,25h_e$ , and of the inner timber member should be  $3,75h_e$ , where  $h_e$  is the embedment depth, see Figure 8.12.

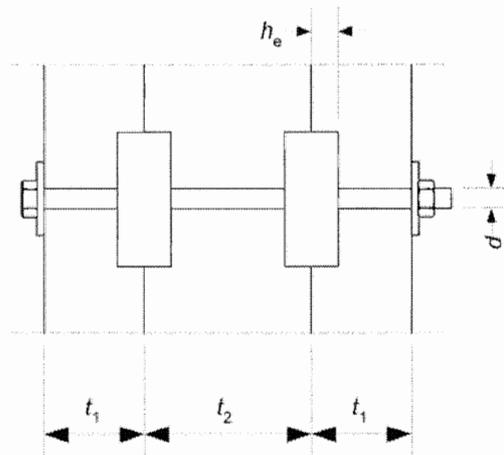


Figure 8.12 – Dimensions for connections with split ring and shear plate connectors

(3) The factor  $k_1$  should be taken as:

$$k_1 = \min \begin{cases} 1 \\ \frac{t_1}{3h_e} \\ \frac{t_2}{5h_e} \end{cases} \quad (8.62)$$

(4) The factor  $k_2$  applies to a loaded end ( $-30^\circ \leq \alpha \leq 30^\circ$ ) and should be taken as:

$$k_2 = \min \left\{ \begin{array}{l} k_a \\ \frac{a_{3,t}}{2d_c} \end{array} \right. \quad (8.63)$$

where:

$$k_a = \begin{cases} 1,25 & \text{for connections with one connector per shear plane} \\ 1,0 & \text{for connections with more than one connector per shear plane} \end{cases} \quad (8.64)$$

$a_{3,t}$  is given in Table 8.7.

For other values of  $\alpha$ ,  $k_2 = 1,0$ .

(5) The factor  $k_3$  should be taken as:

$$k_3 = \min \left\{ \begin{array}{l} 1,75 \\ \frac{\rho_k}{350} \end{array} \right. \quad (8.65)$$

where  $\rho_k$  is the characteristic density of the timber, in  $\text{kg/m}^3$ .

(6) The factor  $k_4$ , which depends on the materials connected, should be taken as:

$$k_4 = \begin{cases} 1,0 & \text{for timber-to-timber connections} \\ 1,1 & \text{for steel-to-timber connections} \end{cases} \quad (8.66)$$

(7) For connections with one connector per shear plane loaded in an unloaded end situation ( $150^\circ \leq \alpha \leq 210^\circ$ ), the condition (a) in expression (8.61) should be disregarded.

(8) For a force at an angle  $\alpha$  to the grain, the characteristic load-carrying capacity,  $F_{\alpha,Rk}$  per connector per shear plane should be calculated using the following expression:

$$F_{v,\alpha,Rk} = \frac{F_{v,0,Rk}}{k_{90} \sin^2 \alpha + \cos^2 \alpha} \quad (8.67)$$

with:

$$k_{90} = 1,3 + 0,001 d_c \quad (8.68)$$

where:

$F_{v,0,Rk}$  is the characteristic load-carrying capacity of the connector for a force parallel to grain according to expression (8.61);

$d_c$  is the connector diameter, in mm.

(9) Minimum spacing and edge and end distances are given in Table 8.7, with the symbols illustrated in Figure 8.7.

Table 8.7 – Minimum spacings and edge and end distances for ring and shear plate connectors.

Spacing and edge/end distances (see Figure 8.7)	Angle to grain	Minimum spacings and edge/end distances
$a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(1,2 + 0,8  \cos \alpha ) d_c$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$1,2 d_c$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$1,5 d_c$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$	$(0,4 + 1,6  \sin \alpha ) d_c$
	$150^\circ \leq \alpha < 210^\circ$	$1,2 d_c$
	$210^\circ \leq \alpha \leq 270^\circ$	$(0,4 + 1,6  \sin \alpha ) d_c$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$(0,6 + 0,2  \sin \alpha ) d_c$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$0,6 d_c$

(10) When the connectors are staggered (see Figure 8.13), the minimum spacings parallel and perpendicular to the grain should comply with the following expression:

$$(k_{a1})^2 + (k_{a2})^2 \geq 1 \quad \text{with} \quad \begin{cases} 0 \leq k_{a1} \leq 1 \\ 0 \leq k_{a2} \leq 1 \end{cases} \quad (8.69)$$

where:

$k_{a1}$  is a reduction factor for the minimum distance  $a_1$  parallel to the grain;

$k_{a2}$  is a reduction factor for the minimum distance  $a_2$  perpendicular to the grain.

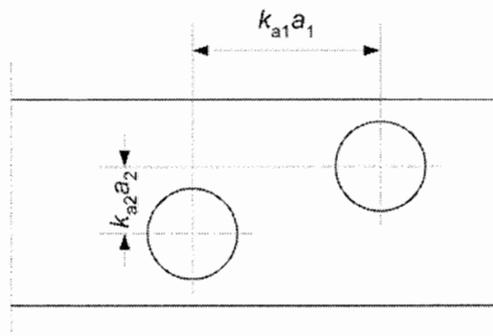


Figure 8.13 – Reduced distances for connectors

(11) The spacing parallel to grain,  $k_{a1} a_1$  may further be reduced by multiplication by a factor  $k_{s,red}$ , with  $0,5 \leq k_{s,red} \leq 1,0$ , provided that the load-carrying capacity is multiplied by a factor

$$k_{R,red} = 0,2 + 0,8 k_{s,red} \quad (8.70)$$

(12) For a row of connectors parallel to the grain, the load-carrying capacity in that direction should be calculated using the effective number of connectors  $n_{ef}$  where:

$$n_{ef} = 2 + \left(1 - \frac{n}{20}\right)(n - 2) \quad (8.71)$$

where:

$n_{ef}$  is the effective number of connectors;

$n$  is the number of connectors in a line parallel to grain.

(13) Connectors should be considered as positioned parallel to the grain where  $k_{a2} a_2 < 0,5 k_{a1} a_1$ .

### 8.10 Toothed-plate connectors

(1) The characteristic load-carrying capacity of connections made using toothed-plate connectors should be taken as the summation of the characteristic load-carrying capacity of the connectors themselves and the connecting bolts according to 8.5.

(2) The characteristic load-carrying capacity  $F_{v,Rk}$  per toothed-plate connector for connectors of type C according to EN 912 (single-sided: type C2, C4, C7, C9, C11; double sided: type C1, C3, C5, C6, C8, C10) and EN 14545 should be taken as:

$$F_{v,Rk} = \begin{cases} 18 k_1 k_2 k_3 d_c^{1,5} & \text{for types C1 to C9} \\ 25 k_1 k_2 k_3 d_c^{1,5} & \text{for types C10 and C11} \end{cases} \quad (8.72)$$

where:

$F_{v,Rk}$  is the characteristic load-carrying capacity per toothed-plate connector, in N.

$k_i$  are modification factors, with  $i = 1$  to 3, defined below.

$d_c$  is:

- the toothed-plate connector diameter for types C1, C2, C6, C7, C10 and C11, in mm;
- the toothed-plate connector side length for types C5, C8 and C9, in mm;
- the square root of the product of both side lengths for types C3 and C4, in mm.

(3) Clause 8.9(2) applies.

(4) The factor  $k_1$  should be taken as:

$$k_1 = \min \begin{cases} 1 \\ \frac{t_1}{3h_c} \\ \frac{t_2}{5h_c} \end{cases} \quad (8.73)$$

where:

$t_1$  is the side member thickness;

$t_2$  is the middle member thickness;

$h_c$  is the tooth penetration depth.  $\square$

(5) The factor  $k_2$  should be taken as:

– For types C1 to C9:

$$k_2 = \min \begin{cases} 1 \\ \frac{a_{3,1}}{1,5 d_c} \end{cases} \quad (8.74)$$

with

$$a_{3,t} = \max \begin{cases} 1,1 d_c \\ 7 d \\ 80 \text{ mm} \end{cases} \quad (8.75)$$

where:

$d$  is the bolt diameter, in mm;

$d_c$  is explained in (2) above.

- For types C10 and C11:

$$k_2 = \min \begin{cases} 1 \\ \frac{a_{3,t}}{2,0 d_c} \end{cases} \quad (8.76)$$

with

$$a_{3,t} = \max \begin{cases} 1,5 d_c \\ 7 d \\ 80 \text{ mm} \end{cases} \quad (8.77)$$

where:

$d$  is the bolt diameter in mm;

$d_c$  is explained in (2) above.

- (6) The factor  $k_3$  should be taken as:

$$k_3 = \min \begin{cases} 1,5 \\ \frac{\rho_k}{350} \end{cases} \quad (8.78)$$

where  $\rho_k$  is the characteristic density of the timber, in  $\text{kg/m}^3$ .

- (7) For toothed-plate connector types C1 to C9, minimum spacings and edge and end distances should be taken from Table 8.8, with the symbols illustrated in Figure 8.7.

- (8) For toothed-plate connector types C10 and C11, minimum spacing and edge and end distances should be taken from Table 8.9, with the symbols illustrated in Figure 8.7.

- (9) Where connectors of types C1, C2, C6 and C7 with circular shape are staggered, 8.9(10) applies.

- (10) For bolts used with toothed-plate connectors, 10.4.3 applies.

Table 8.8 – Minimum spacings and edge and end distances for toothed-plate connector types C1 to C9.

Spacings and edge/end distances (see Figure 8.7)	Angle to grain	Minimum spacings and edge/end distances
$a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(1,2 + 0,3  \cos \alpha ) d_c$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$1,2 d_c$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$2,0 d_c$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$	$(0,9 + 0,6  \sin \alpha ) d_c$
	$150^\circ \leq \alpha < 210^\circ$	$1,2 d_c$
	$210^\circ \leq \alpha \leq 270^\circ$	$(0,9 + 0,6  \sin \alpha ) d_c$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$(0,6 + 0,2  \sin \alpha ) d_c$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$0,6 d_c$

Table 8.9 – Minimum spacings and edge and end distances for toothed-plate connector types C10 and C11.

Spacings and edge/end distances (see Figure 8.7)	Angle to grain	Minimum spacings and edge/end distances
$a_1$ (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(1,2 + 0,8  \cos \alpha ) d_c$
$a_2$ (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$1,2 d_c$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$2,0 d_c$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$	$(0,4 + 1,6  \sin \alpha ) d_c$
	$150^\circ \leq \alpha < 210^\circ$	$1,2 d_c$
	$210^\circ \leq \alpha \leq 270^\circ$	$(0,4 + 1,6  \sin \alpha ) d_c$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$(0,6 + 0,2  \sin \alpha ) d_c$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$0,6 d_c$

## Section 9 Components and assemblies

### 9.1 Components

#### 9.1.1 Glued thin-webbed beams

(1) If a linear variation of strain over the depth of the beam is assumed, the axial stresses in the wood-based flanges should satisfy the following expressions:

$$\sigma_{f,c,max,d} \leq f_{m,d} \quad (9.1)$$

$$\sigma_{f,t,max,d} \leq f_{m,d} \quad (9.2)$$

$$\sigma_{f,c,d} \leq k_c f_{c,0,d} \quad (9.3)$$

$$\sigma_{f,t,d} \leq f_{t,0,d} \quad (9.4)$$

where:

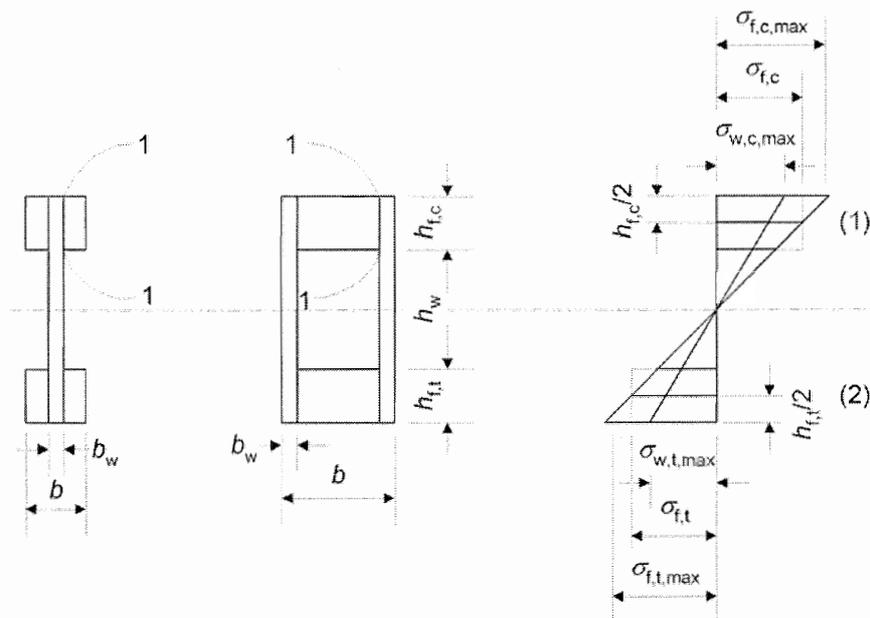
$\sigma_{f,c,max,d}$  is the extreme fibre flange design compressive stress;

$\sigma_{f,t,max,d}$  is the extreme fibre flange design tensile stress;

$\sigma_{f,c,d}$  is the mean flange design compressive stress;

$\sigma_{f,t,d}$  is the mean flange design tensile stress;

$k_c$  is a factor which takes into account lateral instability.



Key:  
(1) compression  
(2) tension

Figure 9.1 – Thin-webbed beams

(3) The factor  $k_c$  may be determined (conservatively, especially for box beams) according to 6.3.2 with

$$\lambda_z = \sqrt{12} \left( \frac{\ell_c}{b} \right) \quad (9.5)$$

where:

$\ell_c$  is the distance between the sections where lateral deflection of the compressive flange is prevented;

$b$  is given in Figure 9.1.

If a special investigation is made with respect to the lateral instability of the beam as a whole, it may be assumed that  $k_c = 1,0$ .

(4) The axial stresses in the webs should satisfy the following expressions:

$$\sigma_{w,c,d} \leq f_{c,w,d} \quad (9.6)$$

$$\sigma_{w,t,d} \leq f_{t,w,d} \quad (9.7)$$

where:

$\sigma_{w,c,d}$  and  $\sigma_{w,t,d}$  are the design compressive and tensile stresses in the webs;

$f_{c,w,d}$  and  $f_{t,w,d}$  are the design compressive and tensile bending strengths of the webs.

(5) Unless other values are given, the design in-plane bending strength of the webs should be taken as the design tensile or compressive strength.

(6)P It shall be verified that any glued splices have sufficient strength.

(7) Unless a detailed buckling analysis is made it should be verified that:

$$h_w \leq 70 b_w \quad (9.8)$$

and

$$F_{v,w,Ed} \leq \begin{cases} b_w h_w \left( 1 + \frac{0,5(h_{f,t} + h_{f,c})}{h_w} \right) f_{v,0,d} & \text{for } h_w \leq 35 b_w \\ 35 b_w^2 \left( 1 + \frac{0,5(h_{f,t} + h_{f,c})}{h_w} \right) f_{v,0,d} & \text{for } 35 b_w \leq h_w \leq 70 b_w \end{cases} \quad (9.9)$$

where:

$F_{v,w,Ed}$  is the design shear force acting on each web;

$h_w$  is the clear distance between flanges;

$h_{f,c}$  is the compressive flange depth;

$h_{f,t}$  is the tensile flange depth;

$b_w$  is the width of each web;

$f_{v,0,d}$  is the design panel shear strength.

(8) For webs of wood-based panels, it should, for sections 1-1 in Figure 9.1, be verified that:

$$\tau_{\text{mean,d}} \leq \begin{cases} f_{v,90,d} & \text{for } h_f \leq 4 b_{\text{ef}} \\ f_{v,90,d} \left( \frac{4b_{\text{ef}}}{h_f} \right)^{0,8} & \text{for } h_f > 4 b_{\text{ef}} \end{cases} \quad (9.10)$$

where:

$\tau_{\text{mean,d}}$  is the design shear stress at the sections 1-1, assuming a uniform stress distribution;

$f_{v,90,d}$  is the design planar (rolling) shear strength of the web;

$h_f$  is either  $h_{f,c}$  or  $h_{f,t}$ .

$$b_{\text{ef}} = \begin{cases} b_w & \text{for boxed beams} \\ b_w / 2 & \text{for I-beams} \end{cases} \quad (9.11)$$

### 9.1.2 Glued thin-flanged beams

(1) This clause assumes a linear variation of strain over the depth of the beam.

(2)P In the strength verification of glued thin-flanged beams, account shall be taken of the non-uniform distribution of stresses in the flanges due to shear lag and buckling.

(3) Unless a more detailed calculation is made, the assembly should be considered as a number of I-beams or U-beams (see Figure 9.2) with effective flange widths  $b_{\text{ef}}$ , as follows:

– For I-beams

$$b_{\text{ef}} = b_{c,\text{ef}} + b_w \quad (\text{or } b_{t,\text{ef}} + b_w) \quad (9.12)$$

– For U-beams

$$b_{\text{ef}} = 0,5b_{c,\text{ef}} + b_w \quad (\text{or } 0,5b_{t,\text{ef}} + b_w) \quad (9.13)$$

The values of  $b_{c,\text{ef}}$  and  $b_{t,\text{ef}}$  should not be greater than the maximum value calculated for shear lag from Table 9.1. In addition the value of  $b_{c,\text{ef}}$  should not be greater than the maximum value calculated for plate buckling from Table 9.1.

(4) Maximum effective flange widths due to the effects of shear lag and plate buckling should be taken from Table 9.1, where  $\ell$  is the span of the beam.

**Table 9.1 – Maximum effective flange widths due to the effects of shear lag and plate buckling**

Flange material	Shear lag	Plate buckling
Plywood, with grain direction in the outer plies:		
– Parallel to the webs	$0,1\ell$	$20h_f$
– Perpendicular to the webs	$0,1\ell$	$25h_f$
Oriented strand board	$0,15\ell$	$25h_f$
Particleboard or fibreboard with random fibre orientation	$0,2\ell$	$30h_f$

(5) Unless a detailed buckling investigation is made, the unrestrained flange width should not be

greater than twice the effective flange width due to plate buckling, from Table 9.1.

(6) For webs of wood-based panels, it should, for sections 1-1 of an I-shaped cross-section in Figure 9.2, be verified that:

$$\tau_{\text{mean,d}} \leq \begin{cases} f_{v,90,d} & \text{for } b_w \leq 8h_f \\ f_{v,90,d} \left( \frac{8h_f}{b_w} \right)^{0,8} & \text{for } b_w > 8h_f \end{cases} \quad (9.14)$$

where:

$\tau_{\text{mean,d}}$  is the design shear stress at the sections 1-1, assuming a uniform stress distribution;  
 $f_{v,90,d}$  is the design planar (rolling) shear strength of the flange.

For section 1-1 of a U-shaped cross-section, the same expressions should be verified, but with  $8h_f$  substituted by  $4h_f$ .

(7) The axial stresses in the flanges, based on the relevant effective flange width, should satisfy the following expressions:

$$\sigma_{f,c,d} \leq f_{f,c,d} \quad (9.15)$$

$$\sigma_{f,t,d} \leq f_{f,t,d} \quad (9.16)$$

where:

$\sigma_{f,c,d}$  is the mean flange design compressive stress;  
 $\sigma_{f,t,d}$  is the mean flange design tensile stress;  
 $f_{f,c,d}$  is the flange design compressive strength;  
 $f_{f,t,d}$  is the flange design tensile strength.

(8)P It shall be verified that any glued splices have sufficient strength.

(9) The axial stresses in the wood-based webs should satisfy the expressions (9.6) to (9.7) defined in 9.1.1

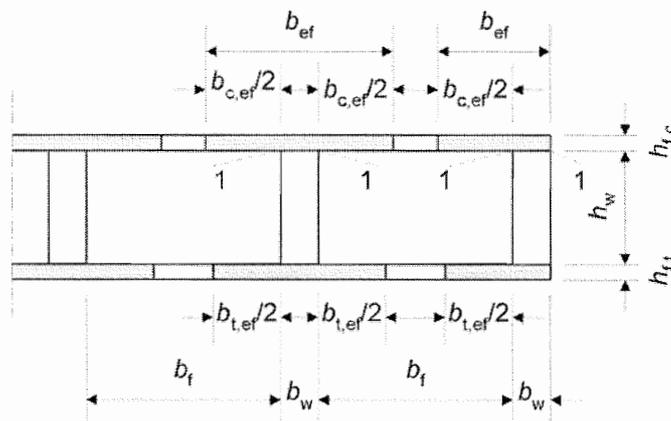


Figure 9.2 – Thin-flanged beam

### 9.1.3 Mechanically jointed beams

(1)P If the cross-section of a structural member is composed of several parts connected by mechanical fasteners, consideration shall be given to the influence of the slip occurring in the

joints.

(2) Calculations should be carried out assuming a linear relationship between force and slip.

(3) If the spacing of the fasteners varies in the longitudinal direction according to the shear force between  $s_{\min}$  and  $s_{\max}$  ( $\leq 4s_{\min}$ ), an effective spacing  $s_{\text{ef}}$  may be used as follows:

$$s_{\text{ef}} = 0,75 s_{\min} + 0,25 s_{\max} \quad (9.17)$$

NOTE: A method for the calculation of the load-carrying capacity of mechanically jointed beams is given in Annex B (Informative).

### 9.1.4 Mechanically jointed and glued columns

(1) P Deformations due to slip in joints, to shear and bending in packs, gussets, shafts and flanges, and to axial forces in the lattice shall be taken into account in the strength verification.

NOTE: A method for the calculation of the load-carrying capacity of I- and box-columns, spaced columns and lattice columns is given in Annex C (Informative).

## 9.2 Assemblies

### 9.2.1 Trusses

(1) For trusses which are loaded predominantly at the nodes, the sum of the combined bending and axial compressive stress ratios given in expressions (6.19) and (6.20) should be limited to 0,9.

(2) For members in compression, the effective column length for in-plane strength verification should generally be taken as the distance between two adjacent points of contraflexure.

(3) For fully triangulated trusses, the effective column length for members in compression should be taken as the bay length, see Figure 5.1, if:

- members are only one bay long, without rigid end connections,
- members are continuous over two or more bays and are not loaded laterally

(4) When a simplified analysis of a fully triangulated truss with punched metal plate fasteners according to clause 5.4.3 has been carried out, the following effective column lengths may be assumed (see Figure 9.3)

- for continuous members without significant end moments and where the bending stresses of the lateral load are at least 40 % of the compressive stresses:
  - in an outer bay: 0,8 times the bay length;
  - in an inner bay: 0,6 the bay length;
  - at a node: 0,6 times the largest adjacent bay length;
- for continuous members with significant end moments where the bending stresses of the lateral load are at least 40 % of the compressive stresses:
  - at the beam end with moment: 0,0 (i.e. no column effect);
  - in the penultimate bay: 1,0 times bay length;
  - remaining bays and nodes: as described above for continuous beams without significant end moments;
- for all other cases 1,0 times bay length.

For the strength verification of members in compression and connections, the calculated axial forces should be increased by 10 %.

(5) When a simplified analysis is carried out for trusses which are loaded at the nodes, the tensile and compressive stress ratios as well as the connection capacity should be limited to 70 %.

(6)P A check shall be made that the lateral (out-of-plane) stability of the truss members is adequate.

(7)P The joints shall be capable of transferring the forces which may occur during handling and erection.

(8) All joints should be capable of transferring a force  $F_{r,d}$  acting in any direction within the plane of the truss.  $F_{r,d}$  should be assumed to be of short-term duration, acting on timber in service class 2, with the value:

$$F_{r,d} = 1,0 + 0,1L \quad (9.18)$$

where:

$F_{r,d}$  is in kN;

$L$  is the overall length of the truss, in m.

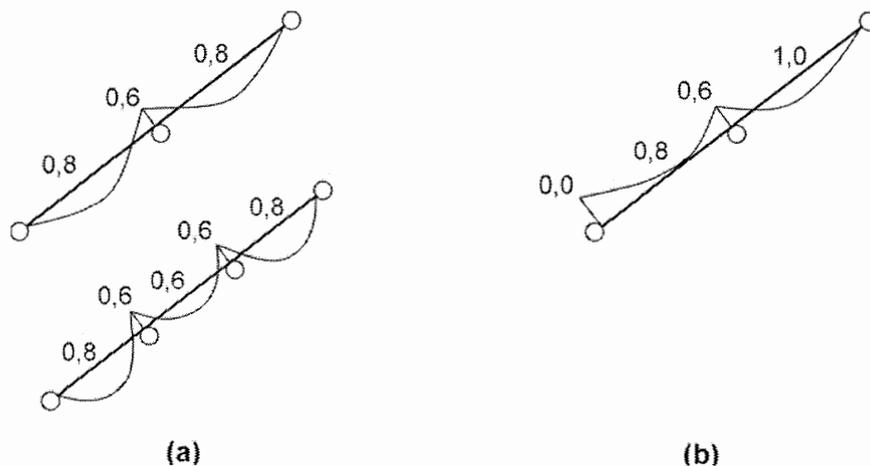


Figure 9.3 – Moment diagrams and effective lengths in compression (a) No significant end moments (b) Significant end moments

### 9.2.2 Trusses with punched metal plate fasteners

(1)P Trusses made with punched metal plate fasteners shall conform to the requirements of EN 14250.

(2) The requirements of 5.4.1 and 9.2.1 apply.

(3) For fully triangulated trusses where a small concentrated force (e.g. a man load) has a component perpendicular to the member of  $< 1,5\text{kN}$ , and where  $\sigma_{c,d} < 0,4 f_{c,d}$ , and  $\sigma_{t,d} < 0,4 f_{t,d}$ , then the requirements of 6.2.3 and 6.2.4 may be replaced by:

$$\sigma_{m,d} \leq 0,75 f_{m,d} \quad (9.19)$$

(4) The minimum overlap of the punched metal plate on any timber member should be at least equal to 40 mm or one third of the height of the timber member, whichever is the greater.

(5) Punched metal plate fasteners used in chord splices should cover at least 2/3 of the required member height.

### 9.2.3 Roof and floor diaphragms

#### 9.2.3.1 General

(1) This section relates to simply supported diaphragms, such as floors or roofs, assembled from sheets of wood-based material fixed by mechanical fasteners to a timber frame.

(2) The load-carrying capacity of fasteners at sheet edges may be increased by a factor of 1,2 over the values given in Section 8.

#### 9.2.3.2 Simplified analysis of roof and floor diaphragms.

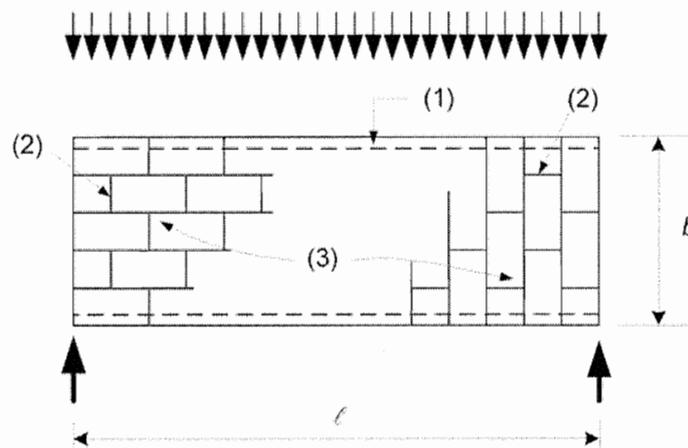
(1) For diaphragms with a uniformly distributed load (see Figure 9.4) the simplified method of analysis described in this section should be used provided that:

- the span  $\ell$  lies between  $2b$  and  $6b$ , where  $b$  is the diaphragm width;
- the critical ultimate design condition is failure in the fasteners (and not in the panels);
- the panels are fixed in accordance with the detailing rules in 10.8.1.

(2) Unless a more detailed analysis is made, the edge beams should be designed to resist the maximum bending moment in the diaphragm.

(3) The shear forces in the diaphragm should be assumed to be uniformly distributed over the width of the diaphragm.

(4) When the sheets are staggered, (see Figure 9.4), the nail spacings along the discontinuous panel edges may be increased by a factor of 1,5 (up to a maximum of 150 mm) without reduction of the load-carrying capacity.



- Key:
- (1) Edge beam
  - (2) Discontinuous edges
  - (3) Panel arrangements

Figure 9.4 – Diaphragm loading and staggered panel arrangements

## 9.2.4 Wall diaphragms

### 9.2.4.1 General

(1)P Wall diaphragms shall be designed to resist both horizontal and vertical actions imposed upon them.

(2)P The wall shall be adequately restrained to avoid overturning and sliding.

(3)P Wall diaphragms deemed to provide resistance to racking shall be stiffened in-plane by board materials, diagonal bracing or moment connections.

(4)P The racking resistance of a wall shall be determined either by test according to EN 594 or by calculations, employing appropriate analytical methods or design models.

(5)P The design of wall diaphragms shall take account of both the material construction and geometric make-up of the wall under consideration.

(6)P The response of wall diaphragms to actions shall be assessed to ensure the construction remains within appropriate serviceability limits.

(7) For wall diaphragms two alternative simplified methods of calculation are given in 9.2.4.2 and 9.2.4.3.

NOTE: The recommended procedure is method A given in 9.2.4.2. National choice may be given in the National annex.

### 9.2.4.2 Simplified analysis of wall diaphragms – Method A

(1) The simplified method given in this subclause should only be applied to wall diaphragms with a tie-down at their end, that is the vertical member at the end is directly connected to the construction below.

(2) The design load-carrying capacity  $F_{v,Rd}$  (the design racking resistance) under a force  $F_{v,Ed}$  acting at the top of a cantilevered panel secured against uplift (by vertical actions or by anchoring) should be determined using the following simplified method of analysis for walls made up of one or more panels, where each wall panel consists of a sheet fixed to one side of a timber frame, provided that:

- the spacing of fasteners is constant along the perimeter of every sheet;
- the width of each sheet is at least  $h/4$ .

(3) For a wall made up of several wall panels, the design racking load-carrying capacity of a wall should be calculated from

$$F_{v,Rd} = \sum F_{i,v,Rd} \quad (9.20)$$

where  $F_{i,v,Rd}$  is the design racking load-carrying capacity of the wall panel in accordance with 9.2.4.2(4) and 9.2.4.2(5).

(4) The design racking load-carrying capacity of each wall panel,  $F_{i,v,Rd}$ , against a force  $F_{i,v,Ed}$  according to Figure 9.5 should be calculated from

$$F_{i,v,Rd} = \frac{F_{f,Rd} b_i c_i}{s} \quad (9.21)$$

where:

$F_{f,Rd}$  is the lateral design capacity of an individual fastener;

$b_i$  is the wall panel width;

$s$  is the fastener spacing.

and

$$c_i = \begin{cases} 1 & \text{for } b_i \geq b_0 \\ \frac{b_i}{b_0} & \text{for } b_i < b_0 \end{cases} \quad (9.22)$$

where:

$$b_0 = h/2$$

$h$  is the height of the wall.

(5) For fasteners along the edges of an individual sheet, the design lateral load-carrying capacity should be increased by a factor of 1,2 over the corresponding values given in Section 8. In determining the fastener spacing in accordance with the requirements of Section 8, the edges should be assumed to be unloaded.

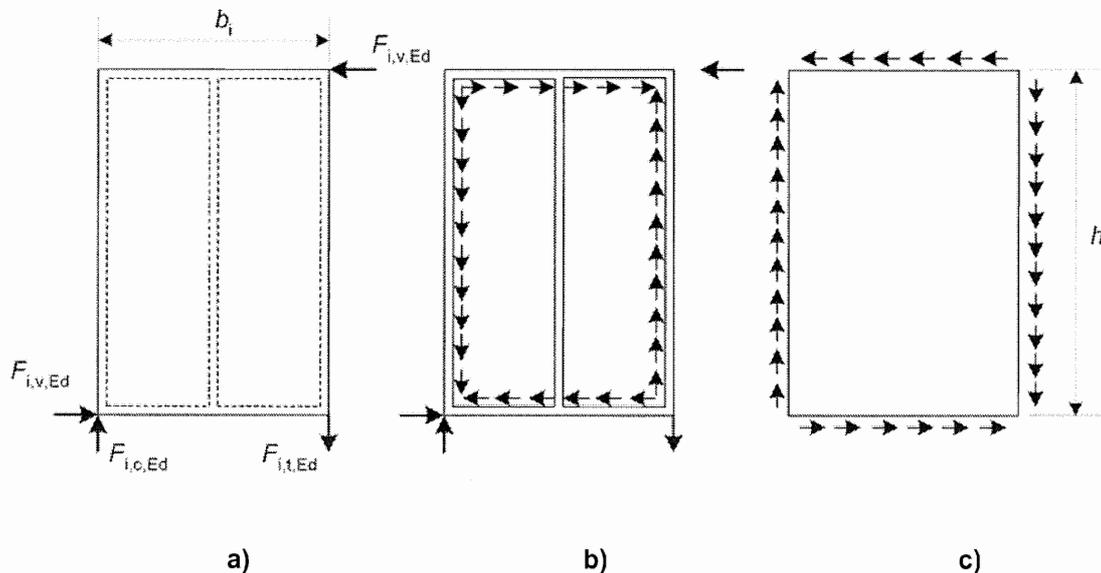


Figure 9.5 – Forces acting on:  
a) wall panel;  
b) framing;  
c) sheet

(6) Wall panels which contain a door or window opening should not be considered to contribute to the racking load-carrying capacity.

(7) For wall panels with sheets on both sides the following rules apply:

- if the sheets and fasteners are of the same type and dimension then the total racking load-carrying capacity of the wall should be taken as the sum of the racking load-carrying capacities of the individual sides
- if different types of sheets are used, 75 % of the racking load-carrying capacity of the weaker side may, unless some other value is shown to be valid, be taken into consideration if fasteners with similar slip moduli are used. In other cases not more than 50 % should be taken into consideration.

(8) The external forces  $F_{i,c,Ed}$  and  $F_{i,t,Ed}$  according to Figure 9.5 should be determined from

$$F_{i,c,Ed} = F_{i,t,Ed} = \frac{F_{i,v,Ed} h}{b_i} \quad (9.23)$$

where  $h$  is the height of the wall.

(9) These forces can either be transmitted to the sheets in the adjacent wall panel or transmitted to the construction situated above or below. When tensile forces are transmitted to the construction situated below, the panel should be anchored by stiff fasteners. Buckling of wall studs should be checked in accordance with 6.3.2. Where the ends of vertical members bear on horizontal framing members, the compression perpendicular to the grain stresses in the horizontal members should be assessed according to 6.1.5.

(10) The external forces which arise in wall panels containing door or window openings and in wall panels of smaller width, see Figure 9.6, can similarly be transmitted to the construction situated above or below.

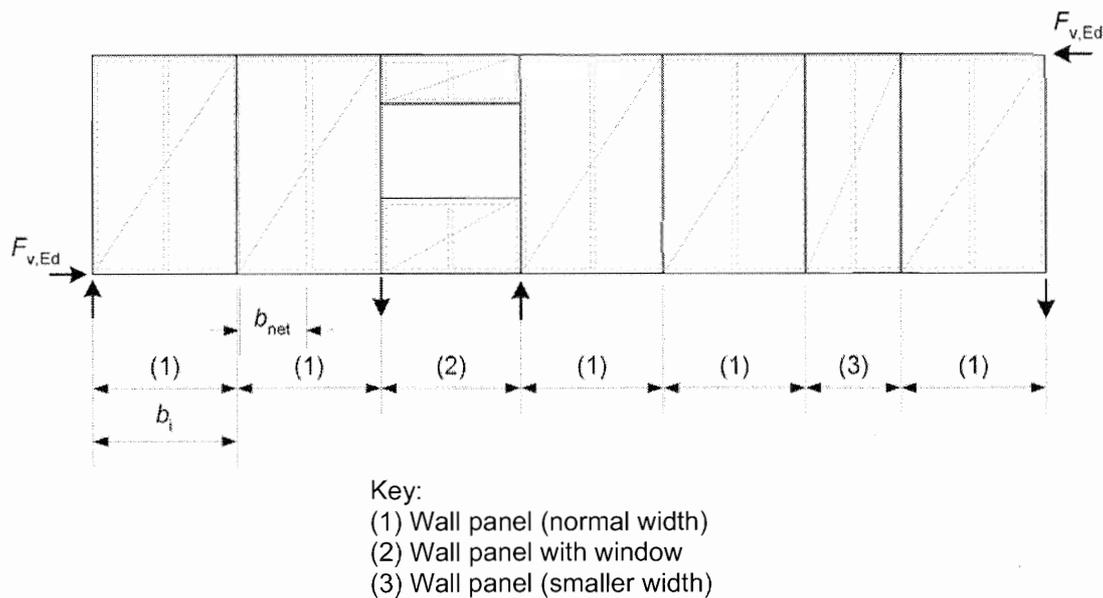


Figure 9.6 – Example of the assembly of wall panels containing a wall panel with a window opening and a wall panel of smaller width

(11) Shear buckling of the sheet may be disregarded, provided that  $\frac{b_{net}}{t} \leq 100$

where:

$b_{net}$  is the clear distance between studs;

$t$  is the thickness of the sheet.

(12) In order that the centre stud may be considered to constitute a support for a sheet, the spacing of fasteners in the centre stud should not be greater than twice the spacing of the fasteners along the edges of the sheet.

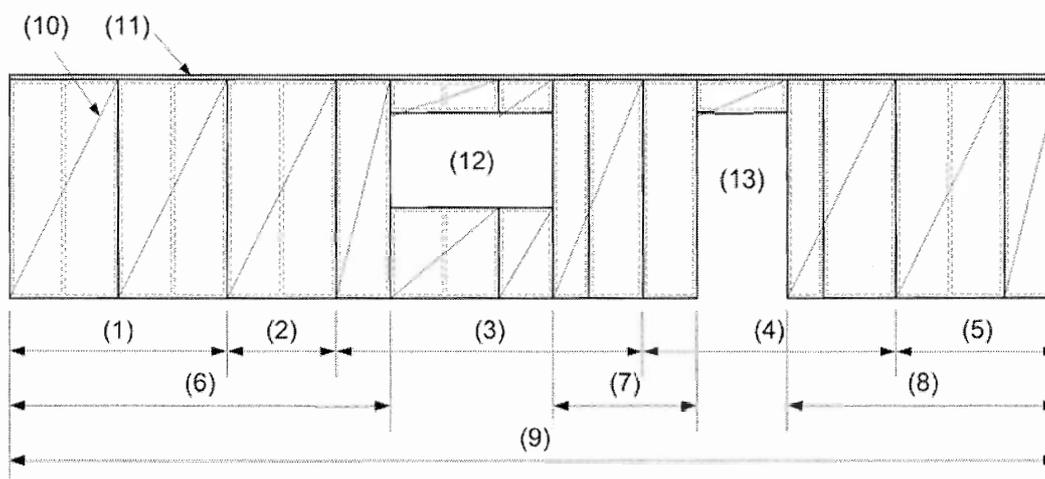
(13) Where each panel consists of a prefabricated wall element, the transfer of shear forces between the separate wall elements should be verified.

(14) In contact areas between vertical studs and horizontal timber members, compression stresses perpendicular to grain should be verified in the timber members.

### 9.2.4.3 Simplified analysis of wall diaphragms – Method B

#### 9.2.4.3.1 Construction of walls and panels to meet the requirements of the simplified analysis

(1) A wall assembly (see Figure 9.7) is comprised of one or more walls with each wall formed from one or more panels, the panels being made from sheets of wood-based panel products, such as those described in 3.5, fastened to a timber frame.



Key:

- |                   |                  |
|-------------------|------------------|
| (1) Wall panel 1  | (2) Wall panel 2 |
| (3) Wall panel 3  | (4) Wall panel 4 |
| (5) Wall panel 5  | (6) Wall 1       |
| (7) Wall 2        | (8) Wall 3       |
| (9) Wall assembly | (10) Sheet       |
| (11) Head binder  | (12) Window      |
| (13) Door         |                  |

**Figure 9.7 – Example of wall assembly consisting of several wall panels**

(2) For a panel to contribute to the in-plane (racking) strength of a wall the width of the panel should be at least the panel height divided by 4. The fastening of the sheets to the timber frame should be by either nails or screws and the fasteners should be equally spaced around the perimeter of the sheet. Fasteners within the perimeter of a sheet should be spaced at not more than twice the perimeter fastener spacing.

(3) Where an opening is formed in a panel, the lengths of panel on each side of the opening should be considered as separate panels.

(4) Where panels are combined to form a wall:

- the tops of individual panels should be linked by a member or construction across the panel joints;
- the required vertical connection strength between two panels should be evaluated but should have a design strength of at least 2,5 kN/m;
- the panels when joined together to form a wall should be able to resist overturning and sliding forces by either anchorage to the supporting structure or the permanent actions applied to the wall or a combination of both effects.

### 9.2.4.3.2 Design procedure

(1) The in-plane design shear (racking) strength  $F_{v,Rd}$  against a force  $F_{v,Ed}$  acting at the top of a cantilevered wall that is secured against uplift and sliding by vertical actions and/or anchorage, should be determined using the following simplified method for the wall construction defined in 9.2.4.3.1.

(2) For a wall assembly made up of several walls, the design racking strength of the wall assembly  $F_{v,Rd}$  should be calculated from

$$F_{v,Rd} = \sum F_{i,v,Rd} \quad (9.24)$$

where:

$F_{i,v,Rd}$  is the design racking strength of a wall in accordance with (3) below.

(3) The design racking strength of a wall  $i$ ,  $F_{i,v,Rd}$ , should be calculated from

$$F_{i,v,Rd} = \frac{F_{f,Rd} b_i}{s_0} k_d k_{i,q} k_s k_n \quad (9.25)$$

where:

$F_{f,Rd}$  is the lateral design capacity of an individual fastener;

$b_i$  is the wall length, in m;

$s_0$  is the basic fastener spacing, in m, see (4) below;

$k_d$  is the dimension factor for the wall, see (4) below;

$k_{i,q}$  is the uniformly distributed load factor for wall  $i$ , see (4) below;

$k_s$  is the fastener spacing factor, see (4) below;

$k_n$  is the sheathing material factor, see (4) below.

(4) The values of  $s_0$ ,  $k_d$ ,  $k_{i,q}$ ,  $k_s$  and  $k_n$  should be calculated as:

$$s_0 = \frac{9,7 d}{\rho_k} \quad (9.26)$$

where:

$s_0$  is the basic fastener spacing, in m;

$d$  is the fastener diameter, in mm;

$\rho_k$  is the characteristic density of the timber frame, in  $\text{kg/m}^3$ ;

$$k_d = \begin{cases} \frac{b_i}{h} & \text{for } \frac{b_i}{h} \leq 1,0 & \text{(a)} \\ \left(\frac{b_i}{h}\right)^{0,4} & \text{for } \frac{b_i}{h} > 1,0 \text{ and } b_i \leq 4,8 \text{ m} & \text{(b)} \\ \left(\frac{4,8}{h}\right)^{0,4} & \text{for } \frac{b_i}{h} > 1,0 \text{ and } b_i > 4,8 \text{ m} & \text{(c)} \end{cases} \quad (9.27)$$

where  $h$  is the height of the wall, in m;

$$k_{i,q} = 1 + \left(0,083 q_i - 0,0008 q_i^2\right) \left(\frac{2,4}{b_i}\right)^{0,4} \quad (9.28)$$

where  $q_i$  is the equivalent uniformly distributed vertical load acting on the wall, in  $\text{kN/m}$ , with  $q_i \geq 0$ , see (5) below;

$$- k_s = \frac{1}{0,86 \frac{s}{s_0} + 0,57} \quad (9.29)$$

where  $s$  is the spacing of the fasteners around the perimeter of the sheets;

$$- k_n = \begin{cases} 1,0 & \text{for sheathing on one side} & (a) \\ \frac{F_{i,v,Rd,max} + 0,5 F_{i,v,Rd,min}}{F_{i,v,Rd,max}} & \text{for sheathing on both sides} & (b) \end{cases} \quad (9.30)$$

where:

$F_{i,v,Rd,max}$  is the design racking strength of the stronger sheathing;

$F_{i,v,Rd,min}$  is the design racking strength of the weaker sheathing.

(5) The equivalent vertical load,  $q_i$ , used to calculate  $k_{i,q}$  should be determined using only permanent actions and any net effects of wind together with the equivalent actions arising from concentrated forces, including anchorage forces, acting on the panel. For the purposes of calculating  $k_{i,q}$ , concentrated vertical forces should be converted into an equivalent uniformly distributed load on the assumption that the wall is a rigid body e.g. for the load  $F_{i,vert,Ed}$  acting on the wall as shown in Figure 9.8

$$q_i = \frac{2 a F_{i,vert,Ed}}{b_i^2} \quad (9.31)$$

where:

$a$  is the horizontal distance from the force  $F$  to the leeward corner of the wall;

$b$  is the length of the wall.

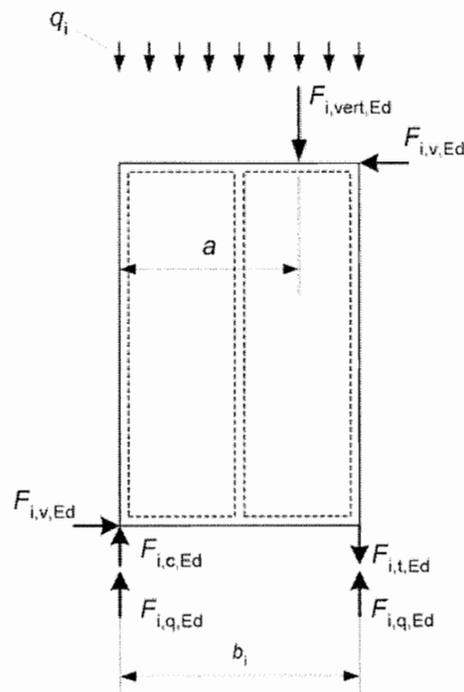


Figure 9.8 – Determination of equivalent vertical action  $q_i$  and reaction forces from vertical and horizontal actions

(6) The external forces  $F_{i,c,Ed}$  and  $F_{i,t,Ed}$  (see Figure 9.8) from the horizontal action  $F_{i,v,Ed}$  on wall  $i$  should be determined from

$$F_{i,c,Ed} = F_{i,t,Ed} = \frac{F_{i,v,Ed} h}{b_1} \quad (9.32)$$

where  $h$  is the height of the wall.

These external forces can be transmitted to either the adjacent panel through the vertical panel-to-panel connection or to the construction above or below the wall. When tensile forces are transmitted to the construction below, the panel should be anchored with stiff fasteners. Compression forces in the vertical members should be checked for buckling in accordance with 6.3.2. Where the ends of vertical members bear on horizontal framing members, the compression perpendicular to the grain stresses in the horizontal members should be assessed according to 6.1.5.

(7) The buckling of the sheets under the action of shear force  $F_{v,Ed}$  may be disregarded provided

$$\frac{b_{net}}{t} \leq 100 \quad (9.33)$$

where:

$b_{net}$  is the clear distance between vertical members of the timber frame;

$t$  is the thickness of the sheathing.

## **9.2.5 Bracing**

### **9.2.5.1 General**

(1)P Structures which are not otherwise adequately stiff shall be braced to prevent instability or excessive deflection.

(2)P The stress caused by geometrical and structural imperfections, and by induced deflections (including the contribution of any joint slip) shall be taken into account.

(3)P The bracing forces shall be determined on the basis of the most unfavourable combination of structural imperfections and induced deflections.

### **9.2.5.2 Single members in compression**

(1) For single elements in compression, requiring lateral support at intervals  $a$  (see Figure 9.9), the initial deviations from straightness between supports should be within  $a/500$  for glued laminated or LVL members, and  $a/300$  for other members.

(2) Each intermediate support should have a minimum spring stiffness  $C$

$$C = k_s \frac{N_d}{a} \quad (9.34)$$

where:

$k_s$  is a modification factor;

$N_d$  is the mean design compressive force in the element;

$a$  is the bay length (see Figure 9.9).

NOTE: For  $k_s$ , see note in 9.2.5.3(1)

(3) The design stabilizing force  $F_d$  at each support should be taken as:

$$F_d = \begin{cases} \frac{N_d}{k_{f,1}} & \text{for solid timber} \\ \frac{N_d}{k_{f,2}} & \text{for glued laminated timber and LVL} \end{cases} \quad (9.35)$$

where  $k_{f,1}$  and  $k_{f,2}$  are modification factors.

NOTE: For  $k_{f,1}$  and  $k_{f,2}$ , see note in 9.2.5.3(1)

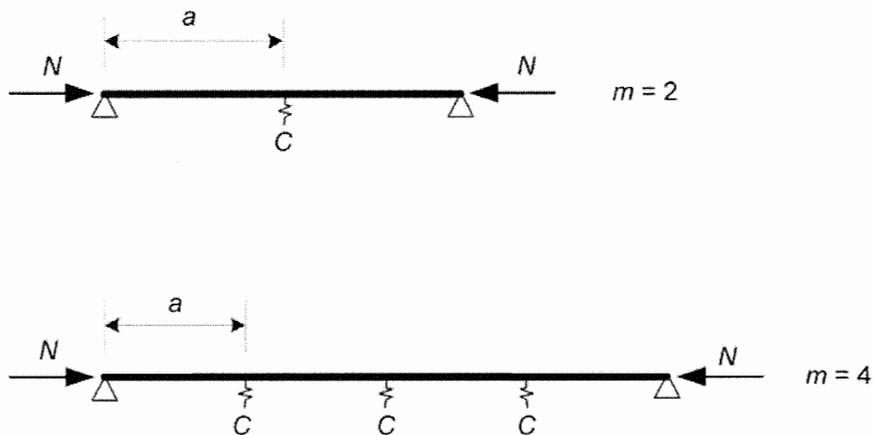


Figure 9.9 – Examples of single members in compression braced by lateral supports.

(4) The design stabilizing force  $F_d$  for the compressive edge of a rectangular beam should be determined in accordance with 9.2.5.2(3) where:

$$N_d = (1 - k_{crit}) \frac{M_d}{h} \quad (9.36)$$

The value of  $k_{crit}$  should be determined from 6.3.3(4) for the unbraced beam, and  $M_d$  is the maximum design moment acting on the beam of depth  $h$ .

### 9.2.5.3 Bracing of beam or truss systems

(1) For a series of  $n$  parallel members which require lateral supports at intermediate nodes A, B, etc. (see Figure 9.10) a bracing system should be provided, which, in addition to the effects of external horizontal load (e.g. wind), should be capable of resisting an internal stability load per unit length  $q$ , as follows:

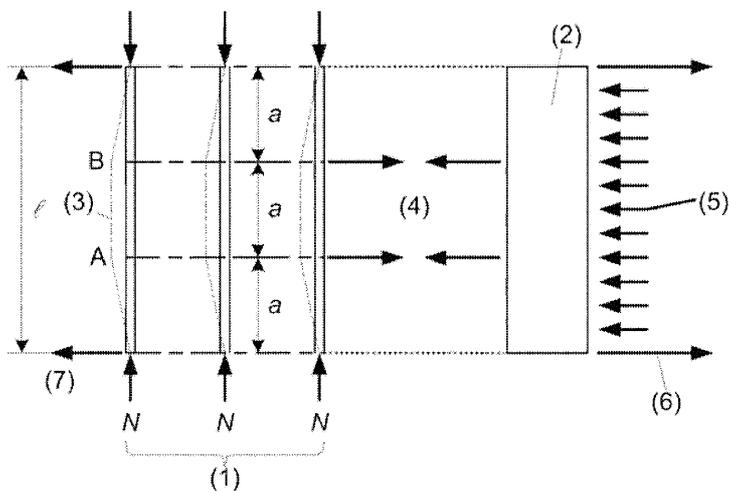
$$q_d = k_\ell \frac{n N_d}{k_{f,3} \ell} \quad (9.37)$$

where:

$$k_\ell = \min \left\{ 1, \sqrt{\frac{15}{\ell}} \right\} \quad (9.38)$$

$N_d$  is the mean design compressive force in the member;

$\ell$  is the overall span of the stabilizing system, in m;  
 $k_{f,3}$  is a modification factor.



Key:

- (1)  $n$  members of truss system
- (2) Bracing
- (3) Deflection of truss system due to imperfections and second order effects
- (4) Stabilizing forces
- (5) External load on bracing
- (6) Reaction forces of bracing due to external loads
- (7) Reaction forces of truss system due to stabilizing forces

Figure 9.10 – Beam or truss system requiring lateral supports

NOTE: The values of the modification factors  $k_s$ ,  $k_{f,1}$ ,  $k_{f,2}$  and  $k_{f,3}$  depend on influences such as workmanship, span etc. Ranges of values are given in Table 9.2 where the recommended values are underlined. The National choice may be given in the National annex.

Table 9.2 – Recommended values of modification factors

Modification factor	Range
$k_s$	<u>4</u> to 1
$k_{f,1}$	<u>50</u> to 80
$k_{f,2}$	<u>80</u> to 100
$k_{f,3}$	<u>30</u> to 80

(2) The horizontal deflection of the bracing system due to force  $q_d$  and any other external load (e.g. wind), should not exceed  $\ell/500$ .

## Section 10 Structural detailing and control

### 10.1 General

(1)P The provisions given in this section are prerequisite requirements for the design rules given in this standard to apply.

### 10.2 Materials

(1) The deviation from straightness measured midway between the supports should, for columns and beams where lateral instability can occur, or members in frames, be limited to 1/500 times the length of glued laminated timber or LVL members and to 1/300 times the length of solid timber. The limitations on bow in most strength grading rules are inadequate for the selection of material for these members and particular attention should therefore be paid to their straightness.

(2) Timber and wood-based components and structural elements should not be unnecessarily exposed to climatic conditions more severe than those expected in the finished structure.

(3) Before being used in construction, timber should be dried as near as practicable to the moisture content appropriate to its climatic condition in the completed structure. If the effects of any shrinkage are not considered important, or if parts that are unacceptably damaged are replaced, higher moisture contents may be accepted during erection provided that it is ensured that the timber can dry to the desired moisture content.

### 10.3 Glued joints

(1) Where bond strength is a requirement for ultimate limit state design, the manufacture of glued joints should be subject to quality control, to ensure that the reliability and quality of the joint is in accordance with the technical specification.

(2) The adhesive manufacturer's recommendations with respect to mixing, environmental conditions for application and curing, moisture content of members and all factors relevant to the proper use of the adhesive should be followed.

(3) For adhesives which require a conditioning period after initial set, before attaining full strength, the application of load to the joint should be restricted for the necessary time.

### 10.4 Connections with mechanical fasteners

#### 10.4.1 General

(1)P Wane, splits, knots or other defects shall be limited in the region of the connection such that the load-carrying capacity of the connection is not reduced.

#### 10.4.2 Nails

(1) Unless otherwise specified, nails should be driven in at right angles to the grain and to such depth that the surfaces of the nail heads are flush with the timber surface.

(2) Unless otherwise specified, slant nailing should be carried out in accordance with Figure 8.8(b).

(3) The diameter of pre-drilled holes should not exceed  $0,8d$ , where  $d$  is the nail diameter.

#### 10.4.3 Bolts and washers

(1) Bolt holes in timber should have a diameter not more than 1 mm larger than the bolt. Bolt

holes in steel plates should have a diameter not more than 2 mm or  $0,1d$  (whichever is the greater) larger than the bolt diameter  $d$ .

(2) Washers with a side length or a diameter of at least  $3d$  and a thickness of at least  $0,3d$  should be used under the head and nut. Washers should have a full bearing area.

(3) Bolts and lag screws should be tightened so that the members fit closely, and they should be re-tightened if necessary when the timber has reached equilibrium moisture content to ensure that the load-carrying capacity and stiffness of the structure is maintained.

(4) The minimum diameter requirements given in Table 10.1 apply to bolts used with timber connectors, where:

$d_c$  is the connector diameter, in mm;

$d$  is the bolt diameter, in mm

$d_1$  is the diameter of centre hole of connector.

**Table 10.1 – Requirements for diameters of bolts used with timber connectors**

Type of connector EN 912	$d_c$	$d$ minimum	$d$ maximum
	mm	mm	mm
A1 – A6	$\leq 130$	12	24
A1, A4, A6	$> 130$	$0,1 d_c$	24
B		$d_1-1$	$d_1$

#### 10.4.4 Dowels

(1) The minimum dowel diameter should be 6 mm. The tolerances on the dowel diameter should be  $-0/+0,1$  mm. Pre-bored holes in the timber members should have a diameter not greater than the dowel.

#### **A1** 10.4.5 Screws

(1) For pre-drilling screws in softwoods with a smooth shank diameter  $d \leq 6$  mm, pre-drilling is not required. For all screws in hardwoods and for pre-drilling screws in softwoods with a diameter  $d > 6$  mm, pre-drilling is required, with the following requirements:

- The lead hole for the shank should have the same diameter as the shank and the same depth as the length of the shank
- The lead hole for the threaded portion should have a diameter of approximately 70 % of the shank diameter.

(2) For timber densities greater than  $500 \text{ kg/m}^3$ , the pre-drilling diameter should be determined by tests.

(3)P Where pre-drilling is applied to selfdrilling screws, the lead hole diameter shall not be greater than the inner thread diameter  $d_1$ . **A1**

#### 10.5 Assembly

(1) The structure should be assembled in such a way that over-stressing of its members or connections is avoided. Members which are warped, split or badly fitting at the joints should be replaced.

## 10.6 Transportation and erection

(1) The over-stressing of members during storage, transportation or erection should be avoided. If the structure is loaded or supported in a different manner during construction than in the finished building the temporary condition should be considered as a relevant load case, including any possible dynamic actions. In the case of structural framework, e.g. framed arches, portal frames, special care should be taken to avoid distortion during hoisting from the horizontal to the vertical position.

## 10.7 Control

(1) It is assumed that a control plan comprises:

- production and workmanship control off and on site;
- control after completion of the structure.

NOTE 1: The control of the construction is assumed to include:

- preliminary tests, e.g. tests for suitability of materials and production methods;
- checking of materials and their identification e.g.:
  - for wood and wood-based materials: species, grade, marking, treatments and moisture content;
  - for glued constructions: adhesive type, production process, glue-line quality;
  - for fasteners: type, corrosive protection;
- transport, site storage and handling of materials;
- checking of correct dimensions and geometry;
- checking of assembly and erection;
- checking of structural details, e.g.:
  - number of nails, bolts etc.;
  - sizes of holes, correct pre-drilling;
  - spacings and distances to end and edge of members;
  - splitting;
- final checking of the result of the production process, e.g. by visual inspection or proof loading.

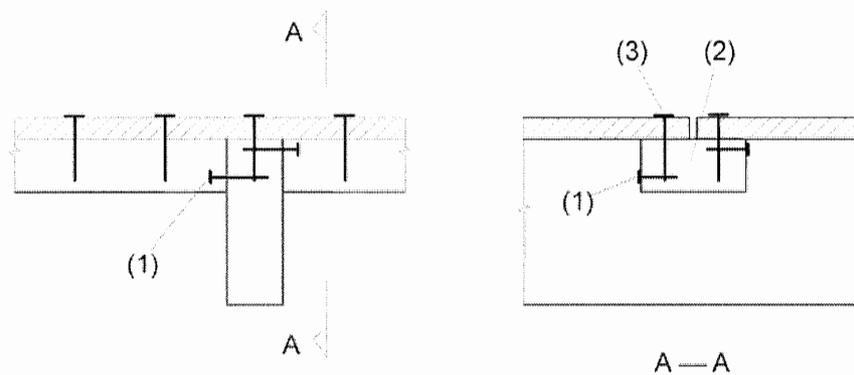
NOTE 2: A control program is assumed to specify the control measures (inspection maintenance) to be carried out in service where long-term compliance with the basic assumptions for the project is not adequately ensured.

NOTE 3: All the information required for the use in service and the maintenance of a structure is assumed to be made available to the person or authority who undertakes responsibility for the finished structure.

## 10.8 Special rules for diaphragm structures

### 10.8.1 Floor and roof diaphragms

(1) The simplified method of analysis given in 9.2.3.2 assumes that sheathing panels not supported by joists or rafters are connected to each other e.g. by means of battens as shown in Figure 10.1. Nails other than smooth nails, as defined in EN 14592, or screws should be used, with a maximum spacing along the edges of the sheathing panels of 150 mm. Elsewhere the maximum spacing should be 300 mm.



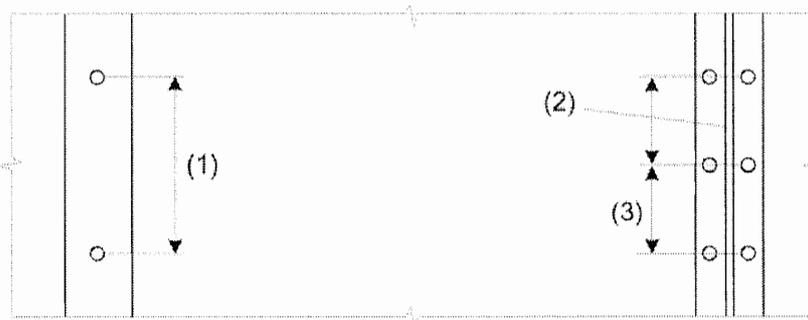
Key:

- (1) Batten slant nailed to joist or rafter
- (2) Batten
- (3) Sheathing nailed to batten

Figure 10.1 – Example of connection of panels not supported by a joist or a rafter

### 10.8.2 Wall diaphragms

(1) The simplified methods of analysis given in 9.2.4.2 and 9.2.4.3 assume that panel fixings have a maximum fastener spacing along the edges of 150 mm for nails, and 200 mm for screws. On internal studs the maximum spacing should be no more than twice the spacing along the edge or 300 mm, whichever is the lesser. See Figure 10.2.



Key:

- (1) Maximum nail spacing 300 mm to intermediate studs
- (2) Panel edge
- (3) Maximum nail spacing 150 mm

Figure 10.2 – Panel fixings

## 10.9 Special rules for trusses with punched metal plate fasteners

### 10.9.1 Fabrication

Note: Requirements for the fabrication of trusses are given in EN 14250.

### 10.9.2 Erection

(1) Trusses should be checked for straightness and vertical alignment prior to fixing the permanent bracing.

(2) When trusses are fabricated, the members should be free from distortion within the limits given in EN 14250. However, if members which have distorted during the period between fabrication and erection can be straightened without damage to the timber or the joints and maintained straight, the truss may be considered satisfactory for use.

(3) The maximum bow  $a_{\text{bow}}$  in any truss member after erection should be limited. Provided that it is adequately secured in the completed roof to prevent the bow from increasing, the permitted value of the maximum bow should be taken as  $a_{\text{bow,perm}}$ .

Note: The recommended range of  $a_{\text{bow,perm}}$  is 10 to 50 mm. The National choice may be given in the National annex.

(4) The maximum deviation  $a_{\text{dev}}$  of a truss from true vertical alignment after erection should be limited. The permitted value of the maximum deviation from true vertical alignment should be taken as  $a_{\text{dev,perm}}$ .

Note: The recommended range of  $a_{\text{dev,perm}}$  is 10 to 50 mm. The National choice may be given in the National annex.

## Annex A (Informative): Block shear and plug shear failure at multiple dowel-type steel-to-timber connections

(1) For steel-to-timber connections comprising multiple dowel-type fasteners subjected to a force component parallel to grain near the end of the timber member, the characteristic load-carrying capacity of fracture along the perimeter of the fastener area, as shown in Figure A.1 (block shear failure) and Figure A.2 (plug shear failure), should be taken as:

$$F_{bs,Rk} = \max \begin{cases} 1,5 A_{net,t} f_{t,0,k} \\ 0,7 A_{net,v} f_{v,k} \end{cases} \quad (A.1)$$

with

$$A_{net,t} = L_{net,t} t_1 \quad (A.2)$$

$$A_{net,v} = \begin{cases} L_{net,v} t_1 & \text{failure modes (c, f, j/l, k, m)} \\ \frac{L_{net,v}}{2} (L_{net,t} + 2t_{ef}) & \text{all other failure modes } \langle A_1 \rangle \end{cases} \quad (A.3)$$

and

$$L_{net,v} = \sum_i l_{v,i} \quad (A.4)$$

$$L_{net,t} = \sum_i l_{t,i} \quad (A.5)$$

– for thin steel plates (for failure modes given in brackets)

$$t_{ef} = \begin{cases} 0,4 t_1 & \text{(a)} \\ 1,4 \sqrt{\frac{M_{y,Rk}}{f_{h,k} d}} & \text{(b)} \end{cases} \quad (A.6)$$

– for thick steel plates (for failure modes given in brackets)

$$t_{ef} = \begin{cases} 2 \sqrt{\frac{M_{y,Rk}}{f_{h,k} d}} & \text{(e)(h)} \\ t_1 \left[ \sqrt{2 + \frac{M_{y,Rk}}{f_{h,k} d t_1^2}} - 1 \right] & \text{(d)(g) } \langle A_1 \rangle \end{cases} \quad (A.7)$$

where

$F_{bs,Rk}$  is the characteristic block shear or plug shear capacity;

$A_{net,t}$  is the net cross-sectional area perpendicular to the grain;

$A_{net,v}$  is the net shear area in the parallel to grain direction;

$L_{net,t}$  is the net width of the cross-section perpendicular to the grain;

$L_{net,v}$  is the total net length of the shear fracture area;

$l_{v,i}, l_{t,i}$  are defined in figure A.1;

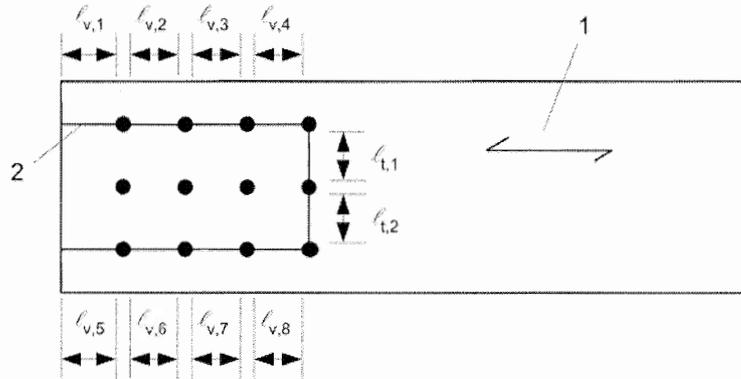
$t_{ef}$  is the effective depth depending of the failure mode of the fastener, see Figure 8.3;

$t_1$  is the timber member thickness or penetration depth of the fastener;

$M_{y,Rk}$  is the characteristic yield moment of the fastener;

- $d$  is the fastener diameter;  
 $f_{t,0,k}$  is the characteristic tensile strength of the timber member;  
 $f_{v,k}$  is the characteristic shear strength of the timber member;  
 $f_{h,k}$  is the characteristic embedding strength of the timber member.

NOTE: The failure modes associated with expressions (A.3), (A.6) and (A.7) are shown in Figure 8.3.



Key:

- 1 Grain direction
- 2 Fracture line

Figure A.1 – Example of block shear failure

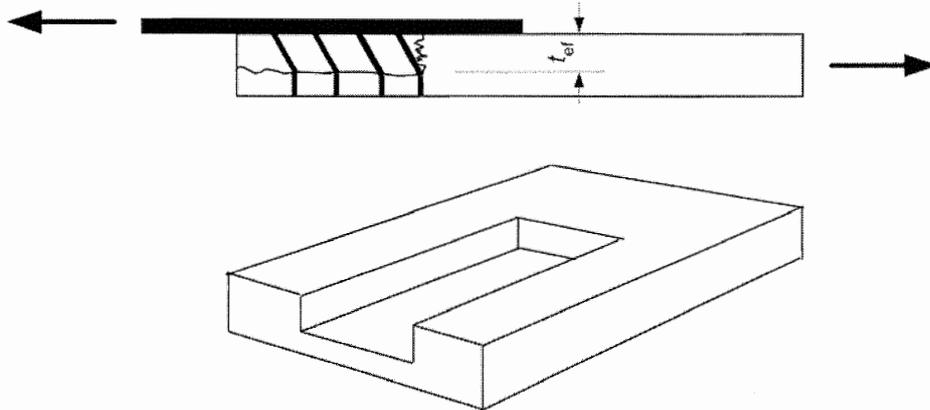


Figure A.2 – Example of plug shear failure

## Annex B (Informative): Mechanically jointed beams

### B.1 Simplified analysis

#### B.1.1 Cross-sections

(1) The cross-sections shown in Figure B.1 are considered in this annex.

#### B.1.2 Assumptions

(1) The design method is based on the theory of linear elasticity and the following assumptions:

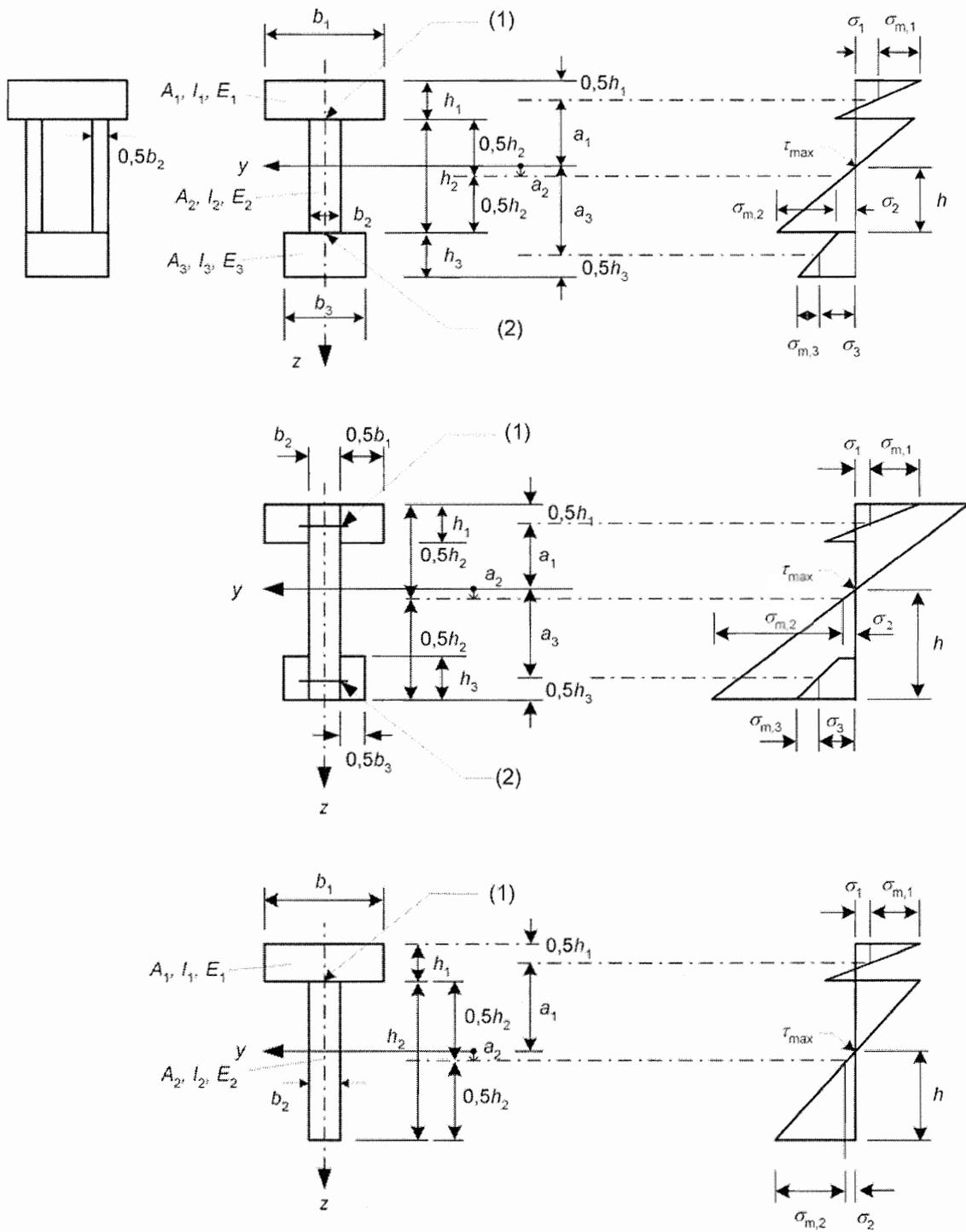
- the beams are simply supported with a span  $\ell$ . For continuous beams the expressions may be used with  $\ell$  equal to 0,8 of the relevant span and for cantilevered beams with  $\ell$  equal to twice the cantilever length
- the individual parts (of wood, wood-based panels) are either full length or made with glued end joints
- the individual parts are connected to each other by mechanical fasteners with a slip modulus  $K$
- the spacing  $s$  between the fasteners is constant or varies uniformly according to the shear force between  $s_{\min}$  and  $s_{\max}$ , with  $s_{\max} \leq 4 s_{\min}$
- the load is acting in the z-direction giving a moment  $M = M(x)$  varying sinusoidally or parabolically and a shear force  $V = V(x)$ .

#### B.1.3 Spacings

(1) Where a flange consists of two parts jointed to a web or where a web consists of two parts (as in a box beam), the spacing  $s_i$  is determined by the sum of the fasteners per unit length in the two jointing planes.

#### B.1.4 Deflections resulting from bending moments

(1) Deflections are calculated by using an effective bending stiffness  $(EI)_{\text{ef}}$  determined in accordance with B.2.



Key:

- (1) spacing:  $s_1$       slip modulus:  $K_1$       load:  $F_1$   
 (2) spacing:  $s_3$       slip modulus:  $K_3$       load:  $F_3$

Figure B.1 – Cross-section (left) and distribution of bending stresses (right). All measurements are positive except for  $a_2$  which is taken as positive as shown.

## B.2 Effective bending stiffness

(1) The effective bending stiffness should be taken as:

$$(EI)_{\text{ef}} = \sum_{i=1}^3 (E_i I_i + \gamma_i E_i A_i a_i^2) \quad (\text{B.1})$$

using mean values of  $E$  and where:

$$A_i = b_i h_i \quad (\text{B.2})$$

$$I_i = \frac{b_i h_i^3}{12} \quad (\text{B.3})$$

$$\gamma_2 = 1 \quad (\text{B.4})$$

$$\gamma_i = \left[ 1 + \pi^2 E_i A_i s_i / (K_i I_i^2) \right]^{-1} \quad \text{for } i = 1 \text{ and } i = 3 \quad (\text{B.5})$$

$$a_2 = \frac{\gamma_1 E_1 A_1 (h_1 + h_2) - \gamma_3 E_3 A_3 (h_2 + h_3)}{2 \sum_{i=1}^3 \gamma_i E_i A_i} \quad (\text{B.6})$$

where the symbols are defined in Figure B.1;

$K_i = K_{\text{ser},i}$  for the serviceability limit state calculations;

$K_i = K_{\text{u},i}$  for the ultimate limit state calculations.

For T-sections  $h_3 = 0$

## B.3 Normal stresses

(1) The normal stresses should be taken as:

$$\sigma_i = \frac{\gamma_i E_i a_i M}{(EI)_{\text{ef}}} \quad (\text{B.7})$$

$$\sigma_{\text{m},i} = \frac{0,5 E_i h_i M}{(EI)_{\text{ef}}} \quad (\text{B.8})$$

## B.4 Maximum shear stress

(1) The maximum shear stresses occur where the normal stresses are zero. The maximum shear stresses in the web member (part 2 in Figure B.1) should be taken as:

$$\tau_{2,\text{max}} = \frac{\gamma_3 E_3 A_3 a_3 + 0,5 E_2 b_2 h_2^2}{b_2 (EI)_{\text{ef}}} V \quad (\text{B.9})$$

## B.5 Fastener load

(1) The load on a fastener should be taken as:

$$F_i = \frac{\gamma_i E_i A_i a_i s_i}{(EI)_{\text{ef}}} V \quad (\text{B.10})$$

where:

$i = 1$  and  $3$ , respectively;

$s_i = s_i(x)$  is the spacing of the fasteners as defined in B.1.3(1).

## Annex C (Informative): Built-up columns

### C.1 General

#### C.1.1 Assumptions

(1) The following assumptions apply:

- the columns are simply supported with a length  $\ell$ ;
- the individual parts are full length;
- the load is an axial force  $F_c$  acting at the geometric centre of gravity, (see however C.2.3).

#### C.1.2 Load-carrying capacity

(1) For column deflection in the y-direction (see Figure C.1 and Figure C.3) the load-carrying capacity should be taken as the sum of the load-carrying capacities of the individual members.

(2) For column deflection in the z-direction (see Figure C.1 and Figure C.3) it should be verified that:

$$\sigma_{c,0,d} \leq k_c f_{c,0,d} \quad (\text{C.1})$$

where:

$$\sigma_{c,0,d} = \frac{F_{c,d}}{A_{\text{tot}}} \quad (\text{C.2})$$

where:

$A_{\text{tot}}$  is the total cross-sectional area;

$k_c$  is determined in accordance with 6.3.2 but with an effective slenderness ratio  $\lambda_{\text{ef}}$  determined in accordance with sections C.2 - C.4.

### C.2 Mechanically jointed columns

#### C.2.1 Effective slenderness ratio

(1) The effective slenderness ratio should be taken as:

$$\lambda_{\text{ef}} = \ell \sqrt{\frac{A_{\text{tot}}}{I_{\text{ef}}}} \quad (\text{C.3})$$

with

$$I_{\text{ef}} = \frac{(EI)_{\text{ef}}}{E_{\text{mean}}} \quad (\text{C.4})$$

where  $(EI)_{\text{ef}}$  is determined in accordance with Annex B (informative).

#### C.2.2 Load on fasteners

(1) The load on a fastener should be determined in accordance with Annex B (informative), where

$$V_d = \begin{cases} \frac{F_{c,d}}{120 k_c} & \text{for } \lambda_{ef} < 30 \\ \frac{F_{c,d} \lambda_{ef}}{3600 k_c} & \text{for } 30 \leq \lambda_{ef} < 60 \\ \frac{F_{c,d}}{60 k_c} & \text{for } 60 \leq \lambda_{ef} \end{cases} \quad (C.5)$$

### C.2.3 Combined loads

(1) In cases where small moments (e.g. from self weight) are acting in addition to axial load, 6.3.2(3) applies.

## C.3 Spaced columns with packs or gussets

### C.3.1 Assumptions

(1) Columns as shown in Figure C.1 are considered, i.e. columns comprising shafts spaced by packs or gussets. The joints may be either nailed or glued or bolted with suitable connectors.

(2) The following assumptions apply:

- the cross-section is composed of two, three or four identical shafts;
- the cross-sections are symmetrical about both axes;
- the number of unrestrained bays is at least three, i.e. the shafts are at least connected at the ends and at the third points;
- the free distance  $a$  between the shafts is not greater than three times the shaft thickness  $h$  for columns with packs and not greater than 6 times the shaft thickness for columns with gussets;

**A1)** – the joints, packs and gussets are designed in accordance with C.3.3; **A1)**

- the pack length  $\ell_2$  satisfies the condition:  $\ell_2/a \geq 1,5$ ;
- there are at least four nails or two bolts with connectors in each shear plane. For nailed joints there are at least four nails in a row at each end in the longitudinal direction of the column;
- the gussets satisfies the condition:  $\ell_2/a \geq 2$ ;
- the columns are subjected to concentric axial loads.

(3) For columns with two shafts  $A_{tot}$  and  $I_{tot}$  should be calculated as

$$A_{tot} = 2A \quad (C.6)$$

$$I_{tot} = \frac{b \left[ (2h + a)^3 - a^3 \right]}{12} \quad (C.7)$$

(4) For columns with three shafts  $A_{tot}$  and  $I_{tot}$  should be calculated as

$$A_{tot} = 3A \quad (C.8)$$

$$I_{tot} = \frac{b \left[ (3h + 2a)^3 - (h + 2a)^3 + h^3 \right]}{12} \quad (C.9)$$

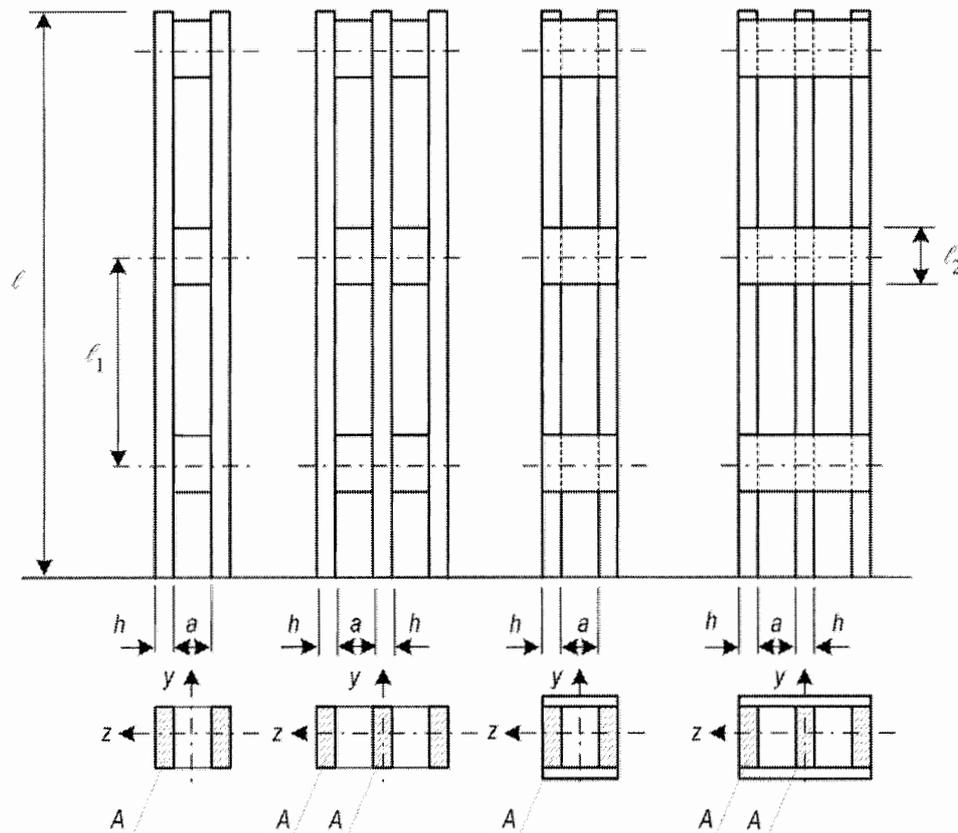


Figure C.1 – Spaced columns

### C.3.2 Axial load-carrying capacity

**A1** (1) For column deflection in the y-direction (see Figure C.1) the load-carrying capacity should be taken as the sum of the load-carrying capacities of the individual members. **A1**

(2) For column deflection in the z-direction C.1.2 applies with

$$\lambda_{\text{ef}} = \sqrt{\lambda^2 + \eta \frac{n}{2} \lambda_1^2} \quad (\text{C.10})$$

where:

$\lambda$  is the slenderness ratio for a solid column with the same length, the same area ( $A_{\text{tot}}$ ) and the same second moment of area ( $I_{\text{tot}}$ ), i.e.,

$$\lambda = \ell \sqrt{A_{\text{tot}} / I_{\text{tot}}} \quad (\text{C.11})$$

$\lambda_1$  is the slenderness ratio for the shafts and has to be set into expression (C.10) with a minimum value of at least 30, i.e.

$$\lambda_1 = \sqrt{12} \frac{\ell_1}{h} \quad (\text{C.12})$$

$n$  is the number of shafts;

$\eta$  is a factor given in Table C.1.

Table C.1 – The factor  $\eta$

	Packs			Gussets	
	Glued	Nailed	Bolted <sup>a</sup>	Glued	Nailed
Permanent/long-term loading	1	4	3,5	3	6
Medium/short-term loading	1	3	2,5	2	4,5
<sup>a</sup> with connectors					

### C.3.3 Load on fasteners, gussets or packs

(1) The load on the fasteners and the gussets or packs are as shown in Figure C.2 with  $V_d$  according to section C.2.2.

(2) The shear forces on the gussets or packs, see Figure C.2, should be calculated from:

$$T_d = \frac{V_d l_1}{a_1} \quad (\text{C.13})$$

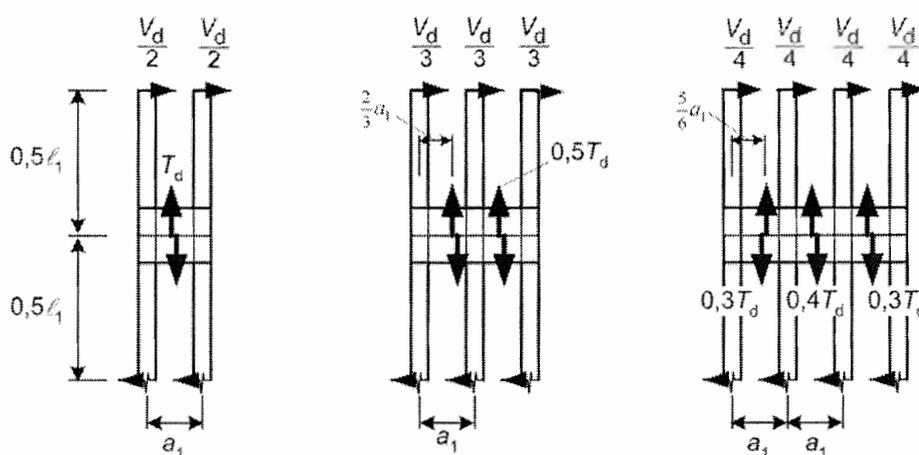


Figure C.2 – Shear force distribution and loads on gussets or packs

## C.4 Lattice columns with glued or nailed joints

### C.4.1 Assumptions

(1) Lattice columns with N- or V-lattice configurations and with glued or nailed joints are considered in this section, see Figure C.3.

(2) The following assumptions apply:

- the structure is symmetrical about the y- and z-axes of the cross-section. The lattice on the two sides may be staggered by a length of  $l_1/2$ , where  $l_1$  is the distance between the nodes;
- there are at least three bays;
- in nailed structures there are at least four nails per shear plane in each diagonal at each nodal point;

- each end is braced;
- the slenderness ratio of the individual flange corresponding to the node length  $\ell_1$  is not greater than 60;
- no local buckling occurs in the flanges corresponding to the column length  $\ell_1$ ;
- the number of nails in the verticals (of an N-truss) is greater than  $n \sin \theta$ , where  $n$  is the number of nails in the diagonals and  $\theta$  is the inclination of the diagonals.

#### **C.4.2 Load-carrying capacity**

(1) For column deflection in the y-direction (see Figure C.2), the load-carrying capacity should be taken as the sum of the load-carrying capacities of the individual flanges.

(2) For column deflection in the z-direction C.1.2 applies with

$$\lambda_{\text{ef}} = \max \begin{cases} \lambda_{\text{tot}} \sqrt{1 + \mu} \\ 1,05 \lambda_{\text{tot}} \end{cases} \quad (\text{C.14})$$

where:

$\lambda_{\text{tot}}$  is the slenderness ratio for a solid column with the same length, the same area and the same second moment of area, i.e.

$$\lambda_{\text{tot}} \approx \frac{2\ell}{h} \quad (\text{C.15})$$

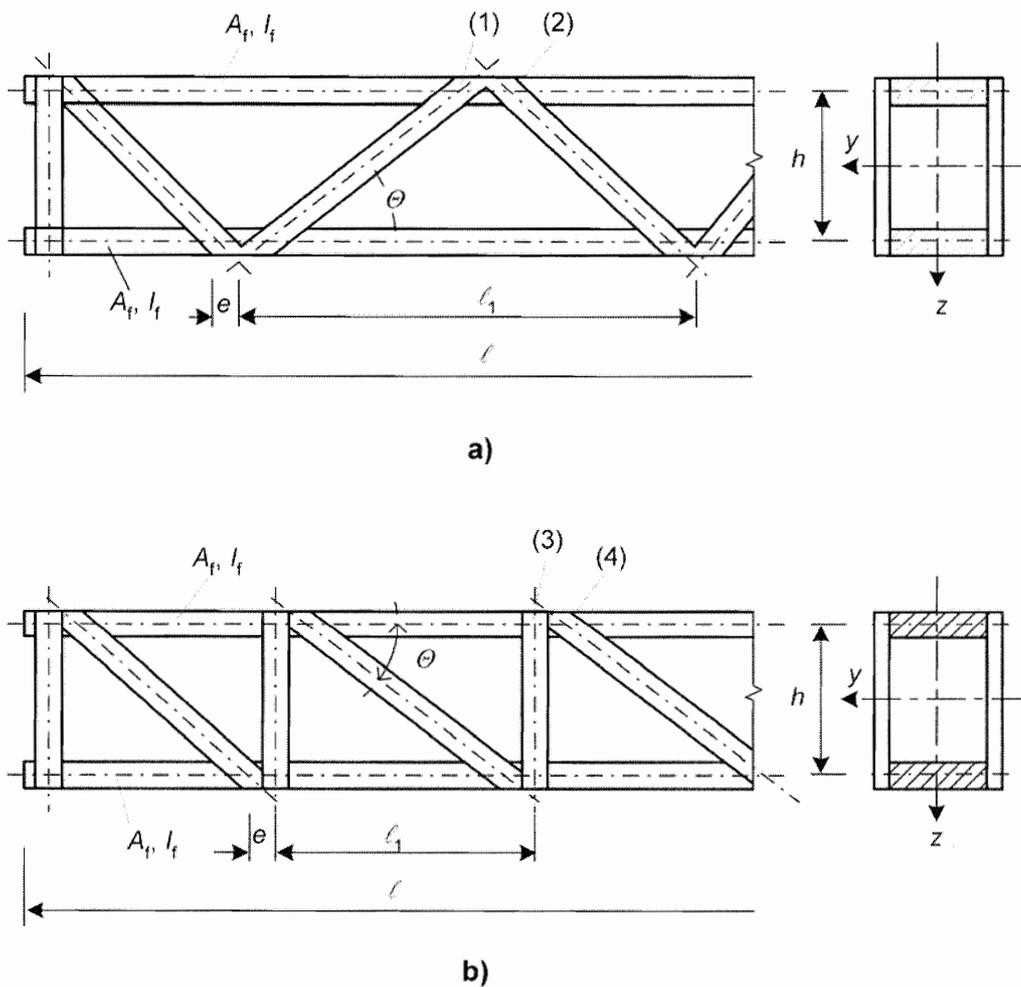
$\mu$  takes the values given in (3) to (6) below.

(3) For a glued V-truss:

$$\mu = 4 \frac{e^2 A_f}{I_f} \left( \frac{h}{\ell} \right)^2 \quad (\text{C.16})$$

where(see Figure C.3):

- $e$  is the eccentricity of the joints;
- $A_f$  is the area of the flange;
- $I_f$  is the second moment of area of the flange;
- $\ell$  is the span;
- $h$  is the distance of the flanges.



Key:

- (1) number of nails:  $n$
- (2) number of nails:  $n$
- (3) number of nails:  $\geq n \sin \theta$
- (4) number of nails:  $n$

Figure C.3 – Lattice columns: (a) V-truss, (b) N-truss

(4) For a glued N-truss:

$$\mu = \frac{e^2 A_f}{I_f} \left( \frac{h}{l} \right)^2 \quad (\text{C.17})$$

(5) For a nailed V-truss:

$$\mu = 25 \frac{h E_{\text{mean}} A_f}{l^2 n K_u \sin 2\theta} \quad (\text{C.18})$$

where:

- $n$  is the number of nails in a diagonal. If a diagonal consists of two or more pieces,  $n$  is the sum of the nails (not the number of nails per shear plane);

$E_{\text{mean}}$  is the mean value of modulus of elasticity;

$K_u$  is the slip modulus of one nail in the ultimate limit state.

(6) For a nailed N-truss:

$$\mu = 50 \frac{h E_{\text{mean}} A_f}{\ell^2 n K_u \sin 2\theta} \quad (\text{C.19})$$

where:

$n$  is the number of nails in a diagonal. If a diagonal consists of two or more pieces,  $n$  is the sum of the nails (not the number of nails per shear plane);

$K_u$  is the slip modulus of one nail for the ultimate limit states.

#### **C.4.3 Shear forces**

(1) C.2.2 applies.

## **Annex D (Informative): Bibliography**

- EN 338 Structural timber – Strength classes
- EN 1194 Glued laminated timber – Strength classes and determination of characteristic values