PD CEN/TS 19103:2021

BSI Standards Publication

Eurocode 5: Design of Timber Structures — Structural design of timber-concrete composite structures — Common rules and rules for buildings

National foreword

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The UK participation in its preparation was entrusted to Technical Committee B/525/5, Structural use of timber.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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European foreword

This document (CEN/TS 19103:2021) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

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This document has been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by this document.

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

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of parts:

— EN 1990 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;

— EN 1998 Eurocode 8: Design of structures for earthquake resistance;

— EN 1999 Eurocode 9: Design of aluminium structures;

— New Eurocodes under development.

0.2 Introduction to EN 1995 (all parts)

(1) EN 1995 (all parts) 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.

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

(3) EN 1995 (all parts) is subdivided into various parts:

— EN 1995-1 *General*;

— EN 1995-2 *Bridges*.

(4) EN 1995-1 “General” in itself does not exist as a physical document, but comprises the following two separate parts:

— EN 1995-1-1 *General – Common rules and rules for buildings*;

— EN 1995-1-2 *General – Structural fire design*.

EN 1995-2 refers to the General rules in EN 1995-1-1.

This document supplements EN 1995.

0.3 Verb forms used in this Technical Specification

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches may be used/adopted where technically justified.

The verb "may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.4 National annex for CEN/TS 19103

This document provides values within notes, indicating where national choices can be made. Therefore, a national document implementing CEN/TS 19103 can have a National Annex containing all Nationally Determined Parameters to be used for the assessment of buildings and civil engineering works in the relevant country.

National choice is allowed in CEN/TS 19103 through the following subclauses:

- 4.3.1.2(5) Average timber moisture content due to the environmental conditions
- 4.4.1.1 Partial factor for shrinkage action
- 4.4.1.2 Partial factor for temperature action
- 4.4.1.2 Partial factor for moisture content action
- 4.4.2 Partial factor for connection shear strength

National choice is allowed in CEN/TS 19103 on the application of the following informative annexes:

- Annex A Yearly variations of moisture content averaged over the timber cross-section for timber-concrete composite structures in variable environmental conditions

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of CEN/TS 19103

(1) CEN/TS 19103 gives general design rules for timber-concrete composite structures.

(2) It provides requirements for materials, design parameters, connections, detailing and execution for timber-concrete composite structures. Recommendations for environmental parameters (temperature and moisture content), design methods and test methods are given in the Annexes.

(3) It includes rules common to many types of timber-concrete composite, but does not include details for the design of glued timber-concrete composites, nor for bridges.

NOTE For the design of glued timber-concrete composites or bridges alternative references are available.

(4) It covers the design of timber-concrete composite structures in both quasi-constant and variable environmental conditions. For ease of use, it provides simple design rules for quasi-constant environmental conditions and more complex rules for variable environmental conditions.

1.2 Assumptions

(1) The general assumptions of EN 1990 apply.

(2) CEN/TS 19103 is intended to be used in conjunction with EN 1990, EN 1991 (all parts), EN 1992 (all parts), EN 1994 (all parts), EN 1995 (all parts), EN 1998 (all parts) when timber structures are built in seismic regions, and ENs for construction products relevant to timber structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

EN 1990:2002[1)], *Eurocode - Basis of structural design*

EN 1991 (all parts), *Eurocode 1: Actions on structures*

EN 1991-1-5:2003, *Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions*

EN 1992-1-1:2004[2)], *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

EN 1993-1-8, *Eurocode 3: Design of steel structures - Part 1-8: Design of joints*

EN 1994-1-1:2004, *Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings*

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1) As impacted by EN 1990:2002/A1:2005.

2) As impacted by EN 1992-1-1:2004/A1:2014.

EN 1994-2:2005, *Eurocode 4 - Design of composite steel and concrete structures - Part 2: General rules and rules for bridges*

EN 1995-1-1:2004[3], *Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings*

EN 14592, *Timber structures - Dowel-type fasteners - Requirements*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990, EN 1995-1-1 and the following apply.

3.1.1
continuous fastener
fastener that is continuous along the length of the timber component

3.1.2
connection
any device or system formed of connected parts and an associated fastener or fasteners as well as, where applicable, notches, which resists slip and transfers the related shear force at the interface between timber and concrete

Note 1 to entry: Examples include dowel-type fasteners of any material, notches, plates and continuous fasteners, any of which can be either mechanically fixed or bonded.

Note 2 to entry: Staples fall beyond the scope of this standard.

3.1.3
inelastic strain
strain which is caused not by stresses but by shrinkage, swelling or thermal expansion, for example

3.1.4
moisture content
mass of water in wood, expressed as a percentage of its oven-dry mass

3.1.5
quasi-constant environmental conditions
environmental conditions where

— timber is installed close to its expected moisture content in use mc_{use} and

— for softwood timber, the variation of average moisture content in use (Δmc, see Formula (4.5)) does not exceed 6 % and

— the temperature variations of the air do not exceed 20 °C

Note 1 to entry: The indoor conditions of a heated building are a typical example of quasi-constant conditions.

3) As impacted by EN 1995-1-1:2004/A1:2008 and EN 1995-1-1:2004/A2:2014.

3.1.6
shrinkage of concrete
decrease in dimension of a piece of concrete due to the hardening process

3.1.7
shrinkage of timber
decrease in dimension of a piece of timber due to reduction of moisture content

3.1.8
swelling of timber
increase in dimension of a piece of timber due to increase of moisture content

3.1.9
thermal expansion
linear thermal expansion between given temperatures

3.1.10
variable environmental conditions
conditions that do not comply with quasi-constant environmental conditions

Note 1 to entry: Typical examples where variable environmental conditions can be experienced are balconies, unheated roof spaces and outdoor covered and uncovered spaces.

3.2 Symbols and abbreviations

For the purposes of this document, the symbols given in EN 1995-1-1 and the following apply.

Latin upper-case letters

A_1	Area of cross-section 1
A_2	Area of cross-section 2
A_b	Area of longitudinal reinforcement in concrete flange
$A_\mathrm{conc,ef}$	Effective area of the concrete cross-section
A_s	Area of longitudinal reinforcement in concrete flange
A_sf	Area of transverse reinforcement in concrete flange
A_tim	Area of the timber cross-section
$C_\mathrm{J,sls}$	Coefficient which considers the interaction between vertical load q_d and inelastic strains in terms of slip in the joint
$C_\mathrm{p,sls}$	Coefficient which correlates the inelastic strains with a fictitious load
E_1	Modulus of elasticity of cross-section 1
E_2	Modulus of elasticity of cross-section 2
E_conc	Modulus of elasticity of concrete
$E_\mathrm{conc,fin}$	Effective long-term modulus of elasticity of concrete
E_k	Characteristic combination of actions
$E_\mathrm{q,per}$	Quasi-permanent combination of actions

E_{u}	Fundamental combination of actions
E_{s}	Design value of the modulus of elasticity of the steel reinforcement as given in EN 1992-1-1:2004, 3.2.7
E_{tim}	Mean modulus of elasticity of timber parallel to the grain
$E_{tim,fin}$	Effective long-term modulus of elasticity of timber parallel to the grain
$(EI)_{i}$	Bending stiffness of the cross-section i
$(EI)_{ef,EC5\text{-}AnnexB}$	Effective bending stiffness according to EN 1995-1-1:2004, Annex B
$(EI)_{ef,sls}$	Modified effective bending stiffness according to EN 1995-1-1:2004, Annex B, which accounts for the interaction between vertical load and inelastic strains
$F_{ax,Rk}$	Characteristic axial withdrawal capacity of the fastener
F_{est}	Estimated load-carrying capacity as defined in accordance with EN 26891 and used in determining the mean slip modulus for ultimate limit states
F_{max}	Characteristic load-carrying capacity in an Annex C test, as determined in accordance with EN 26891
F_{Rd}	Design load-carrying capacity for a notched connection
$F_{t,Ed}$	Design tensile force between the timber and the concrete cross-section
$F_{v,Ed}$	Design shear force per connection
$F_{v,Rd}$	Design load-carrying capacity per connection
$F_{v,Rk}$	Characteristic connection shear strength
$F_{v,R,t_c,k}$	Characteristic load-carrying capacity in shear per connection at time t_c
I_{1}	Moment of inertia of cross-section 1
I_{2}	Moment of inertia of cross-section 2
I_{tim}	Moment of inertia of the timber cross-section
K	Stiffness of the connection
K_{max}	Maximum stiffness of the connection
K_{min}	Minimum stiffness of the connection
K_{ref}	Reference stiffness of connection
K_{ser}	Slip modulus for serviceability limit states
$K_{ser,fin}$	Final slip modulus
K_{ser,t_c}	Mean slip modulus for serviceability at time t_c
K_{u}	Instantaneous slip modulus of the connection for ultimate limit states
$K_{u,fin}$	Final slip modulus for ultimate limit states
K_{u,t_c}	Slip modulus for ultimate limit states at time t_c

L	Span of the beam
$M(q_d + 0.8p_{sls})$	Resulting bending moment due to external loads and part (80 %) of the fictitious load equivalent to inelastic strains
$M(q_d)$	Resulting bending moment due to external load only
M_i	Bending moment of component *i*
$M_{max,2}$	Maximum bending moment in cross-section 2
M_{tim}	Bending moment in the timber cross-section
N_i	Axial force in cross-section *i*
$N_{max,2}$	Maximum axial force in cross-section 2
N_{tim}	Axial force in the timber cross-section
$T_{0,conc}$	Initial average temperature in the concrete at time t_c
$T_{0,tim}$	Initial average temperature in the timber at time t_c
$T_{max,conc}$	Maximum temperature in the concrete (averaged over the cross-section)
$T_{max,tim}$	Maximum temperature in the timber (averaged over the cross-section)
$T_{min,conc}$	Minimum temperature in the concrete (averaged over the cross-section)
$T_{min,tim}$	Minimum temperature in the timber (averaged over the cross-section)
V_{max}	Effective maximum shear force
$V(q_d)$	Resulting shear force due to external load
V_u	Ultimate slip determined in an Annex C test in accordance with EN 12512
X_d	Design value of a strength property of timber or a wood-based product

Latin lower-case letters

a	Distance
a_1	spacing of fasteners parallel to the grain
$a_{1\leftrightarrow c}$	Distance from the centroid of cross-section 1 to the centroid of the effective composite cross-section
a_{3c}	Distance between the fastener and the unloaded edge
a_{3t}	Distance between the fastener and the loaded edge
a_4	spacing of fasteners perpendicular to the grain
a_s	Cross-sectional area of the transverse reinforcement of the concrete flange when checking in-plane shear in the concrete
a_b	Cross-sectional area of the longitudinal reinforcement of the concrete flange when checking in-plane shear in the concrete
b_{conc}	Width of the concrete
$b_{conc,ef}$	Effective width of the concrete

b_n	Notch width
b_{tim}	Width of the timber
b_w	Width of the timber element (in verification of concrete for in-plane shear)
$c_{min,dur}$	Minimum concrete cover for durability of steel reinforcement
c_{nom}	Nominal concrete cover
d	Fastener diameter or rebar diameter
d_g	Diameter of the aggregate
d_r	Diameter of the concrete reinforcement bar diameter
f_{cd}	Design value of the compressive strength of concrete
f_{ck}	Characteristic compressive cylinder strength of the concrete at 28 days
f_{ctd}	Design value of the tensile strength of concrete
$f_{c,h,2,k}$	characteristic embedment strength of the concrete member for evaluation of the load-carrying capacity based on the Johansen models
f_{vcd}	Effective design shear strength for the concrete
$f_{v,t,d}$	Design shear strength of the timber member
f_{yd}	Design value of the yield strength of steel reinforcement
$h_{s,conn}$	Nominal height of the connector
h_f	Thickness of the concrete flange
h_n	Notch depth
k_{def}	Deformation factor of timber
k_{def}'	Deformation factor for connections between concrete and timber
k_{mod}	Modification factor for duration of load and moisture content for timber strength
k_{mod}'	Modification factor for duration of load and moisture content for the strength of connections between concrete and timber
k_s	Mean slip modulus for serviceability limit states, determined from Annex C tests in accordance with EN 26891
k_{tc}	Coefficient for concrete, taking into account the effect of high sustained loads on compressive strength
l_n	Notch length
l_s	Distance between notches
l_v	Length of timber in front of the notch
mc	Moisture content of timber (averaged over the timber cross-section)
mc_0	Moisture content of timber at time t_c

mc_{max}	Maximum moisture content of timber during annual cycles
mc_{min}	Minimum moisture content of timber during annual cycles
mc_{use}	Expected moisture content of timber in use (mean over the year, averaged over the timber cross-section)
mc_{var}	Variation in moisture content over an annual cycle
p_{sls}	Fictitious vertical load which represents the effects of inelastic strains on the structure
s_{ef}	Effective spacing of the connections
s_f	Spacing of the transverse reinforcement bars in the concrete slab when checking in-plane actions in the concrete
s_l	Longitudinal spacing of the fasteners when checking in-plane shear in the concrete
s_{max}	Maximum spacing of the connections
s_{min}	Minimum spacing of the connections
s_t	Transverse spacing of the fasteners when checking in-plane shear in the concrete
t	A point in time
t_0	The time when the concrete achieves the design strength or the time when the design-imposed load is applied to the composite structure, whichever is the earlier
t_∞	Time for design for long-term condition
t_c	Time according to EN 13670:2009, 8.5(6) when curing and protection of the concrete are complete
t_p	Time of removal of props
t_s	Age of concrete at which drying shrinkage begins according to EN 1992-1-1:2004, 3.1.4(6)
q_d	Design value of the external loads
$u_{u,tc}$	Mean ultimate slip
w_k	Crack width in concrete
w_{max}	Recommended maximum crack width in concrete EN 1992-1-1:2004, Table 7.1N
z	Distance between the centres of gravity of the cross-sections

Greek upper-case letters

ΔF_d	Design longitudinal shear over a certain length of beam in verification of concrete for in-plane shear (including diaphragm actions)
Δmc	Total change over the annual cycle of the average timber moisture content due to environmental conditions
Δmc^-	Reduction in average moisture content in timber over the annual cycle with respect to the expected moisture content in use mc_{use}
Δmc^+	Increase in average moisture content in timber over the annual cycle with respect to the expected moisture content in use mc_{use}

Δmc_{calc}	Timber moisture content variation (averaged over the timber cross-section) to be considered in the design
Δmc_{d}	Difference between the average timber moisture content in use mc_{use} and the average value mc_0 at time t_c
ΔT_{E}	Non-linear temperature difference component of the composite section
ΔT_{MY}	Temperature difference component about the z-z axis, with linear variation
ΔT_{MZ}	Temperature difference component about the y-y axis, with linear variation
$\Delta T_{u,conc^-}$	Change in the average temperature of the concrete in the composite section from initial to minimum
$\Delta T_{u,conc^+}$	Change in the average temperature of the concrete in the composite section from initial to maximum
$\Delta T_{u,i,calc}$	Temperature variation of the cross-section *i* (1 or 2) to be considered in the design
$\Delta T_{u,tim^-}$	Change in the average temperature of the timber in the composite section from initial to minimum
$\Delta T_{u,tim^+}$	Change in the average temperature of the timber in the composite section from initial to maximum
$\Delta \varepsilon$	Difference in inelastic strain between the timber part and the concrete part
Δx	Length under consideration in verification of concrete for in-plane shear (including diaphragm actions)

Greek lower-case letters

α	Angle of a notch
$\alpha_{c,T}$	Coefficient of linear thermal expansion of concrete
$\alpha_{i,T}$	Coefficient of thermal expansion of the cross-section *i*
$\alpha_{t,u}$	Coefficient of linear moisture expansion of timber parallel to the grain
$\alpha_{t,T}$	Coefficient of linear thermal expansion of timber parallel to the grain
γ_1	Composite factor of the concrete cross-section
γ_{SH}	Partial factor for shrinkage action
γ_{T}	Partial factor for thermal action
γ_{u}	Partial factor for moisture content action
γ_{v}	Partial factor for connection shear strength
ε_{conc}	Shrinkage of concrete according to EN 1992-1-1:2004
$\varepsilon_{ef,conc}$	Effective shrinkage of concrete
ε_{i}	Inelastic strain of the cross-section
θ	Angle of the concrete strut

ν	Strength reduction factor for concrete cracked in shear
ρ_{m}	Mean value of timber member density
$\sigma_{\mathrm{conc,c,d}}$	Design compressive stress in the concrete member, caused by axial force and bending
$\sigma_{\mathrm{conc,t,d}}$	Design tensile stress in the concrete member, caused by axial force and bending
τ_{Ed}	Design longitudinal shear stress for verification of concrete for in-plane shear
φ	Creep coefficient of the concrete
$\psi_{0,\mathrm{mc}}$	Factor for combination value of yearly variations of average timber moisture content
$\psi_{1,\mathrm{mc}}$	Factor for frequent value of yearly variations of average timber moisture content
$\psi_{2,\mathrm{mc}}$	Factor for quasi-permanent value of average timber moisture content variations
ψ_{conc}	Coefficient for the effect of composite action on the creep coefficient of the concrete cross-section
ψ_{conn}	Coefficient for the effect of composite action on the creep coefficient of the connection
ψ_{tim}	Coefficient for the effect of composite action on the creep coefficient of the timber cross-section

4 Basis of design

4.1 General rules

(1) The design of timber-concrete composite structures shall be in accordance with the general rules stated in EN 1990 and the supplementary provisions for timber-concrete composite structures stated in this document.

(2) The basic requirements of EN 1990:2002, Clause 2, are deemed to be satisfied for timber-concrete composite structures when all the following are applied:

— Limit state design in conjunction with the partial factor method in accordance with EN 1990;

— Actions in accordance with EN 1991 (all parts);

— Action combinations in accordance with EN 1990;

— Resistances, durability and serviceability in accordance with this standard, EN 1992-1-1, EN 1994-1-1 and EN 1995-1-1.

4.2 Principles of limit state design

(1) In addition to the general principles stated in EN 1995-1-1:2004, 2.2 the effects of construction sequence and changes of environmental conditions should be considered where relevant for the design.

NOTE Refer to 4.3.1.2 for the effect of changes of environmental conditions, where relevant.

(2) Due to the different creep behaviours of the concrete, the timber and the connection system, the final long-term stress distribution in the composite structure at ultimate limit state, due to the fundamental combination of actions E_{u}, should be calculated by superimposing:

— the stress distribution in the long-term due to the quasi-permanent combination of actions $E_{q,per}$ calculated using the effective moduli of elasticity of concrete $E_{conc,fin}$ and timber $E_{tim,fin}$ and the effective slip modulus of the connection $K_{u,fin}$ (refer to 4.3.2(7))

and

— the instantaneous stress distribution due to the difference between the fundamental combination of actions E_u and the quasi-permanent combination of actions E_{qper}, calculated using the moduli of elasticity of concrete E_{conc} and timber E_{tim} and the slip modulus of the connection K_u.

(3) Due to the different creep behaviours of the concrete, the timber and the connection system, the final deformation of the composite structure at serviceability limit state, due to the characteristic combination of actions E_k, should be calculated by superimposing:

— the total deformation in the long-term due to the quasi-permanent combination of actions $E_{q,per}$ calculated using the effective moduli of elasticity of concrete $E_{conc,fin}$ and timber $E_{tim,fin}$ and the effective slip modulus of the connection $K_{ser,fin}$ (refer to 4.3.2(7))

and

— the instantaneous deformation due to the difference between the characteristic combination of actions E_k and the quasi-permanent combination of actions E_{qper}, calculated using the moduli of elasticity of concrete E_{conc} and timber E_{tim} and the slip modulus of the connection K_{ser}.

4.3 Basic variables

4.3.1 Actions and environmental influences

4.3.1.1 General – Quasi-constant environmental conditions

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

(2) Duration of load and moisture content should be taken into account in the design for mechanical resistance and serviceability in accordance with EN 1995-1-1 and in accordance with this document.

NOTE Duration of load and moisture content affect the strength and stiffness properties of timber as well as the strength and stiffness properties of the connection between timber and concrete.

(3) Shrinkage of concrete should be considered in design for verification of both the ultimate limit state and the serviceability limit state. For timber-concrete composite structures with a cast-in-situ concrete slab, the shrinkage of concrete should be calculated from the time of concrete curing t_c, irrespective of whether the timber member is propped or not.

NOTE The calculation of the effects of concrete shrinkage is given in Annex 5.1,2,e shrinkage is regarded as an inelastic strain applied to the timber-concrete composite structure.

(4) The increase in moisture content of the timber due to casting may be disregarded (see 11.1 (3)).

4.3.1.2 General – Variable environmental conditions

(1) In variable environmental conditions, the provisions given in 4.3.1.2 shall apply in addition to the provisions in 4.3.1.1.

(2) Due to the different linear expansion coefficients of timber and concrete, temperature differences should be considered for verifications of both the ultimate limit state and the serviceability limit state. In most cases, only the variations of the uniform temperature component in the concrete ($\Delta T_{u,conc}$) and the timber ($\Delta T_{u,tim}$), as defined in Clause 4(3) of EN 1991-1-5:2003, need to be considered. The effects of the linear and non-linear temperature difference components of the composite section (ΔT_{MY}, ΔT_{MZ} and ΔT_{E}), as defined in 4(3) of EN 1991-1-5:2003, may be neglected.

(3) The maximum and minimum temperature differences in the concrete and timber should be calculated using Formulae (4.1) to (4.4):

$$\Delta T_{u,conc}{}^{+} = T_{max,conc} - T_{0,conc} \quad (4.1)$$

$$\Delta T_{u,tim}{}^{+} = T_{max,tim} - T_{0,tim} \quad (4.2)$$

and

$$\Delta T_{u,conc}{}^{-} = T_{min,conc} - T_{0,conc} \quad (4.3)$$

$$\Delta T_{u,tim}{}^{-} = T_{min,tim} - T_{0,tim} \quad (4.4)$$

where

$\Delta T_{u,conc}{}^{+}$ is the change in the average temperature of the concrete in the composite section from initial to maximum;

$T_{max,conc}$ is the maximum value of the average temperature in the concrete (refer to EN 1991-1-5:2003, Clause 5);

$T_{0,conc}$ is the initial average temperature in the concrete at time t_c when the concrete has been cured;

$\Delta T_{u,tim}{}^{+}$ is the change in the average temperature of the timber in the composite section from initial to maximum;

$T_{max,tim}$ is the maximum value of the average temperature in the timber (refer to EN 1991-1-5:2003, Clause 5);

$T_{0,tim}$ is the initial average temperature in the timber at time t_c when the concrete has been cured;

NOTE If the initial temperatures when the structure is erected are unknown, reference can be made to EN 1991-1-5:2003, Annex A.

$\Delta T_{\text{u,conc}}^{-}$ is the change in the average temperature of the concrete in the composite section from initial to minimum;

$T_{\text{min,conc}}$ is the minimum value of the average temperature in the concrete (refer to EN 1991-1-5:2003, Clause 5);

$\Delta T_{\text{u,tim}}^{-}$ is the change in the average temperature of the timber in the composite section from initial to minimum;

$T_{\text{min,tim}}$ is the minimum value of the average temperature in the timber (refer to EN 1991-1-5:2003, Clause 5).

(4) Shrinkage/swelling of timber in the longitudinal direction due to reductions/increases in moisture content should be considered in design for verification of both the ultimate limit state and the serviceability limit state. In general, shrinkage/swelling of the timber should be calculated by considering only the variation over time of moisture content, averaged over the timber cross-section.

(5) When the timber is conditioned (see EN 1995-1-1:2004, 10.2) to the expected moisture content in use mc_{use}, the annual variation of the average timber moisture content due to the environmental conditions Δmc (see Formula (4.5)) should be taken into account:

— The increase ($\Delta mc^{+} = \Delta mc/2 > 0$) and the decrease $\Delta mc^{-} = \Delta mc/2 < 0$) with respect to the expected moisture content in use mc_{use} should be considered.

NOTE 1 Guidance for the evaluation of the variation Δmc is given in Annex A.

$$\Delta mc = mc_{\text{max}} - mc_{\text{min}} \tag{4.5}$$

where

mc_{max} is the maximum annual average timber moisture content;

mc_{min} is the minimum annual average timber moisture content.

— For structures in Europe, moisture content variations should be considered with a sign opposite to that of the temperature variations

NOTE 2 $\Delta mc^{+} > 0$; $\Delta T_{\text{u,conc}}^{-} < 0$ and $\Delta T_{\text{u,tim}}^{-} < 0$

and

$\Delta mc^{-} < 0$; $\Delta T_{\text{u,conc}}^{+} > 0$ and $\Delta T_{\text{u,tim}}^{+} > 0$.

(6) When timber is not conditioned to the expected moisture content in use mc_{use}, in addition to 4.3.1.2(5), the difference between the average timber moisture content due to the environmental conditions in use mc_{use} and the average value mc_{0} at the time t_{c} when the concrete was cured should also be considered in design.

NOTE Annex B Formulae provide a method for calculation of the effects of temperature differences and shrinkage/swelling of timber. In these Formulae, temperature difference, shrinkage of concrete and shrinkage/swelling of timber are inelastic strains applied to the timber-concrete composite structure.

4.3.1.3 Load duration classes – Quasi-constant environmental conditions

(1) The load duration classes according to EN 1995-1-1 shall apply.

(2) The effect of concrete shrinkage on the timber-concrete composite structure should be assigned to the permanent load duration class.

4.3.1.4 Load duration classes – Variable environmental conditions

(1) For timber-concrete composite structures in variable environmental conditions, the provisions given in 4.3.1.4 shall apply in addition to the provisions in 4.3.1.3.

(2) The effect of timber shrinkage or swelling due to a difference Δmc between the average moisture content of the timber cross-section in use mc_{use} and the initial average timber moisture content during erection mc_0 (refer to 4.3.1.2(6)) may be assigned to the permanent load duration class.

(3) Considering the differences between the maximum and minimum temperatures in the concrete and timber (refer to 4.3.1.2(3)) and the initial temperature when the structure is erected ($\Delta T_{\mathrm{u,conc}}{}^{+}$, $\Delta T_{\mathrm{u,tim}}{}^{+}$ and $\Delta T_{\mathrm{u,conc}}{}^{-}$, $\Delta T_{\mathrm{u,tim}}{}^{-}$), the effect may be assigned to the medium-term load duration class.

(4) The effect of the annual variation in average timber moisture due to environmental conditions Δmc (refer to 4.3.1.2(5)) may be assigned to the medium-term load duration class.

(5) In the absence of specific values provided in 5.1,2,e 1 of Annex A of EN 1990:2002, the same factors as for temperature variations should be assumed for combination $\psi_{0,\mathrm{mc}}$, frequent $\psi_{1,\mathrm{mc}}$ and quasi-permanent $\psi_{2,\mathrm{mc}}$ values for yearly variations of average timber moisture content Δmc.

4.3.1.5 Service classes

(1) The service classes according to EN 1995-1-1 shall apply.

(2) The interface and the connection between timber and concrete shall be designed such that they are in either service class 1 or in service class 2.

4.3.2 Material and product properties

(1) Unless stated otherwise by this standard, the time-dependent behaviour of timber (creep coefficients) may be obtained from EN 1995-1-1:2004, 3.1.4.

(2) Unless stated otherwise by this standard, the time-dependent behaviour of concrete (creep and shrinkage) should be obtained from EN 1992-1-1:2004, 3.1.4.

(3) The influence of load duration and moisture on the strength of timber shall be considered using the modification factor k_{mod} according to EN 1995-1-1:2004, 3.13.

(4) The influence of load duration and moisture on the strength of connections between concrete and timber shall be considered using the modification factor k_{mod}'. Unless provided by product specifications, the modification factor k_{mod}' should be as given by Formula (4.6):

$$k_{\mathrm{mod}}' = \sqrt{k_{\mathrm{tc}} k_{\mathrm{mod}}} \tag{4.6}$$

where

k_{tc} is the coefficient for concrete, taking into account the effect of high sustained loads on compressive strength EN 1992-1-1:2004, 3.1.6(1);

k_{mod} is the modification factor for duration of load and moisture content for timber strength according to EN 1995-1-1:2004, 3.1.3.

(5) The influence of load duration and moisture on timber deformation shall be considered using the deformation factor k_{def} according to EN 1995-1-1:2004, 3.14.

(6) The influence of load duration and moisture on deformation of the connection between concrete and timber shall be considered using the deformation factor k_{def}'. Unless provided by product specifications, the deformation factor k_{def}' should be as given by Formula (4.7):

$$k_{\mathrm{def}}' = 2k_{\mathrm{def}} \tag{4.7}$$

where

k_{def} is the deformation factor for timber according to EN 1995-1-1:2004, 3.1.4.

(7) The effect of creep of materials on the stress distribution and deformation of the composite structure in the long term should be considered using the effective moduli of concrete $E_{\mathrm{conc,fin}}$ and timber $E_{\mathrm{tim,fin}}$ and an effective slip modulus of the connection $K_{\mathrm{ser,fin}}$ or $K_{\mathrm{u,fin}}$ in the elastic analysis, see Formulae (4.8) to (4.11):

$$E_{\mathrm{conc,fin}} = \frac{E_{\mathrm{conc,t_0}}}{1+\psi_{\mathrm{conc}}\varphi(\infty,\mathrm{t_0})} \tag{4.8}$$

$$E_{\mathrm{tim,fin}} = \frac{E_{\mathrm{tim}}}{1+\psi_{\mathrm{tim}}\,k_{\mathrm{def}}} \tag{4.9}$$

$$K_{\mathrm{ser,fin}} = \frac{K_{\mathrm{ser}}}{1+\psi_{\mathrm{conn}}\,k_{\mathrm{def}}'} \tag{4.10}$$

$$K_{\mathrm{u,fin}} = \frac{K_{\mathrm{u}}}{1+\psi_{\mathrm{conn}}\,k_{\mathrm{def}}'} \tag{4.11}$$

where

$E_{\mathrm{conc,fin}}$ is the effective long-term modulus of elasticity of concrete;

$E_{\mathrm{conc,t_0}}$ is the modulus of elasticity of concrete at time t_0 according to EN 1992-1-1:2004, 3.1.3 (3);

ψ_{conc} is the coefficient accounting for composite action influence on the effective creep coefficient of concrete (refer to 7.1.2 (6));

$\varphi(\infty,t_0)$ is the creep coefficient of concrete from time t_0 to the end of the service life;

$E_{\mathrm{tim,fin}}$ is the effective long-term modulus of elasticity of timber;

E_{tim} is the mean modulus of elasticity of timber;

ψ_{tim} is the coefficient accounting for composite action influence on the effective creep coefficient of timber (refer to 7.1.2 (6));

k_{def}' is the deformation factor for the connection (refer to 4.3.2 (6));

$K_{ser,fin}$	is the final slip modulus of the connection for the serviceability limit state design
K_{ser}	is the mean slip modulus of the connection for the serviceability limit state design (refer to 10.2);
ψ_{conn}	is the coefficient accounting for composite action influence on the effective creep coefficient of the connection (refer to 7.1.2 (6));
$K_{u,fin}$	is the final slip modulus of the connection for the ultimate limit state design;
K_{u}	is the mean slip modulus of the connection for the ultimate limit state design (refer to 10.2).

4.4 Verification using the partial factor method

4.4.1 Design values of actions

4.4.1.1 Design values of actions – Quasi-constant environmental conditions

(1) Concrete shrinkage shall be calculated as described in Clause 5.

NOTE Unless a different value is stated in the National Annex, the partial factor for shrinkage action γ_{SH} is 1.35.

4.4.1.2 Design values of actions – Variable environmental conditions

(1) For timber-concrete composite structures in variable environmental conditions, the provisions given in 4.4.1.2 shall apply in addition to the provisions in 4.4.1.1.

(2) The temperature differences in concrete and timber should be calculated according to EN 1991-1-5.

NOTE 1 Unless a different value is stated in the National Annex, the partial factor for temperature action γ_{T} is 1.35.

NOTE 2 Information on annual variations in average timber moisture content in the timber cross-section is given in Annex A.

NOTE 3 Unless a different value is stated in the National Annex, the partial factor for moisture content action γ_{u} is 1.35.

(3) The maximum moisture content in use should be estimated according to EN 1995-1-1:2004, 2.3.1.3, depending on the service class.

NOTE In service class 1, the average moisture content in most softwoods will not exceed 12 % (EN 1995-1-1:2004, 2.3.1.3(2)), and in service class 2 the average moisture content in most softwoods will not exceed 20 % (EN 1995-1-1:2004, 2.3.1.3(3)).

4.4.2 Design values of material or product properties

(1) Unless an upper estimate of strength is required, partial factors should be applied to lower characteristic or nominal strengths.

(2) The design compressive strength of concrete f_{cd} and the design tensile strength of concrete f_{ctd} are given by EN 1992-1-1:2004, 3.1.6.

(3) The design value of the yield strength of steel reinforcement f_{yd} is given by subclause 3.2.7 (2) and Figure 3.8 of EN 1992-1-1:2004.

(4) The design value of a strength property of timber or a wood-based product X_{d} is given by EN 1995-1-1:2004, 2.4.1.

(5) For the connection between concrete and timber, the design value of shear strength $F_{\mathrm{v,Rd}}$ should be as given by Formula (4.12):

$$F_{\mathrm{v,Rd}} = k_{\mathrm{mod}}' \frac{F_{\mathrm{v,Rk}}}{\gamma_{\mathrm{v}}} \tag{4.12}$$

where

k_{mod}' is the modification factor for duration of load and moisture content;

$F_{\mathrm{v,Rk}}$ is the characteristic connection shear strength;

γ_{v} is the partial factor for connection shear strength.

NOTE Unless a different value is stated in the National Annex, γ_{v} is 1.25.

4.4.3 Design values of geometrical data

(1) Geometrical data for cross-sections and systems may be taken from harmonized European Standards (hENs), product standards or drawings for execution, and treated as nominal values.

5 Materials

5.1 Quasi-constant environmental conditions

5.1.1 Concrete

(1) Unless stated otherwise by this document, specified properties and related conditions of concrete that are required for design to this Technical Specification shall comply with EN 1992-1-1:2004, 3.1 for normal weight concrete and EN 1992-1-1:2004, 11.3 for lightweight concrete.

NOTE This standard does not cover the design of composite structures with concrete strength classes lower than C12/15 and LC12/13 and higher than C60/75 and LC60/66.

(2) Creep and shrinkage of concrete may be determined from Annex B of EN 1992-1-1:2004 taking into account ambient humidity, the dimensions of the element and the composition of the concrete.

5.1.2 Reinforcing steel

(1) Specified properties and related conditions of reinforcing steel that are required for design to this Technical Specification shall comply with EN 1992-1-1:2004, 3.2.

(2) For composite structures, the design value of the modulus of elasticity E_{s} should be taken as given in EN 1992-1-1:2004, 3.2.7.

5.1.3 Timber

(1) Strength-graded structural timber, glued solid timber, glued laminated timber, structural finger-jointed timber, cross-laminated timber, laminated veneer lumber and wood-based panels may be used in timber-concrete composite structures.

(2) Specified properties and related conditions of timber that are required for design to this Technical Specification shall comply with EN 1995-1-1:2004, Clause 3.

5.1.4 Connections

(1) Metal fasteners and welding consumables shall comply with EN 1993-1-8, EN 1995-1-1 and EN 14592.

5.2 Variable environmental conditions

5.2.1 General

(1) For timber-concrete composite beams in variable environmental conditions, the provisions given in 5.2 shall apply in addition to the provisions of 5.1.

5.2.2 Concrete

(1) The coefficient of linear expansion $\alpha_{c,T}$ should be taken from EN 1992-1-1:2004, 3.1.3(5), for calculation of inelastic strains due to temperature variations.

5.2.3 Timber

(1) The coefficient of linear expansion $\alpha_{t,T}$ should be taken from Annex C of EN 1991-1-5:2003 for calculation of inelastic strains due to temperature variations.

(2) For calculation of inelastic strains due to moisture content variations for softwood, unless provided by product specifications, the moisture expansion coefficient $\alpha_{t,u}$ parallel to the grain should be assumed to be equal to 0.000 1 per 1 % of moisture content variation.

6 Durability

6.1 General

(1) The relevant provisions stated in EN 1990, EN 1992 (all parts) and EN 1995 (all parts) shall be followed.

(2) Detailing of the shear connection shall be in accordance with Clause 11.

(3) Durable timber-concrete floors should be designed and maintained to ensure that wooden parts remain dry throughout their service life.

6.2 Timber decking for composite slabs in buildings

(1) The exposed surfaces of timber decking should be protected appropriately in order to resist deterioration through exposure to deleterious atmospheric conditions.

6.3 Resistance to corrosion

(1) Metal fasteners and other structural connections should be corrosion-resistant or protected against corrosion in accordance with EN 1995-1-1:2004, 4.2 or more stringent national demands.

NOTE The degree of protection required depends on the environment to which metal fasteners and other structural connections are to be exposed. EN 1995-1-1:2004, Table 4.1, shows specific treatments for different service classes.

(2) Steel parts other than fasteners should be protected according to EN 1090-2.

(3) The effect of chemical treatment of timber, or timber with high acidic content, on the corrosion protection of fasteners should be considered.

7 Structural analysis

7.1 Modelling of the composite structure

7.1.1 General

(1) The flexibility of the connection between timber and concrete shall be considered when determining internal forces and deformation.

(2) A rigorous analysis of the internal forces and deformations should be carried out.

NOTE Guidance on the γ-method used for analysing composite structures is given in Annex B of EN 1995-1-1 (including the assumptions).

(3) Providing that the effective spacing of the connections is less than or equal to 5 % of the distance between the points of contraflexure, even distribution of the connection stiffness along the beam axis (smearing) may be used.

(4) If the spacing of the connections is greater than 5 % of the distance between the points of contraflexure then, when smearing, the connections should be distributed in proportion to the shear force. In the absence of a more precise model, only 70 % of the axial stiffness of the attached cross-section should be considered for the calculation of stresses and deformation. 100 % of the axial stiffness of the cross-section should be considered for the calculation of the shear force in the connection.

(5) If the spacing and/or stiffness of the connections are varied in proportion to the shear force, the effective spacing may be determined by Formula (7.1):

$$s_{ef} = 0,75\, s_{min} \frac{K_{ref}}{K_{max}} + 0,25\, s_{max} \frac{K_{ref}}{K_{min}} \tag{7.1}$$

where

s_{ef} is the effective spacing of the connections;

s_{min} is the minimum spacing of the connections;

K_{ref} is the reference stiffness of the connection used with the corresponding value of s_{ef};

K_{max} is the maximum stiffness of the connection;

K_{min} is the minimum stiffness of the connection;

s_{max} is the maximum spacing of the connections or the maximum distance between the connection and the point of zero shear force.

(6) Plasticity of the connection may be used in the design, provided that inelastic strains due to shrinkage and temperature/moisture variations are considered where relevant.

(7) Statically indeterminate composite systems may only be considered if both the concrete topping and timber beam are continuous over the entire length. Otherwise, the effect of the discontinuity of the elements should be considered in detail with respect to both the reduction in stiffness and the load-carrying capacity of the continuous composite system.

(8) A linear-elastic shear force-slip relationship should be used with K_u, $K_{u,fin}$, K_{ser} and $K_{ser,fin}$ according to Clauses 4 and 10.

(7) For timber, a linear-elastic stress-strain relationship may be assumed.

(8) For concrete in compression, a linear-elastic stress-strain relationship may be assumed.

(9) For uncracked concrete in tension, a linear-elastic stress-strain relationship may be assumed. Cracked concrete in tension should be assumed to have no tensile strength.

(10) The possibility of concrete cracking should be considered when determining:

— the distribution of member forces, moments and reactions;

— the distribution of internal forces;

— the deformation;

— the strength capacity at the ultimate limit state design value of the concrete slab.

The cracked area may be considered to be a non-load-bearing layer between the timber and the compression area in the concrete.

NOTE The cracked area is that caused by all load combinations up to the point in time that is considered.

(11) The effective width of the concrete slab should be determined in accordance with EN 1994-1-1:2004, 5.4.1.2.

(12) Reinforced concrete design should be carried out taking into account strain compatibility with the timber at the ultimate limit state assuming plane sections. Unless it is shown that sufficient strain develops in the section to justify the use of the plastic strength of the steel reinforcement and of the concrete, elastic design should be used for the reinforced concrete.

7.1.2 Time-dependent behaviour

(1) The effects of creep and shrinkage/swelling of concrete and timber, temperature variations and the creep of the connection shall be considered in the ultimate and serviceability limit states (refer to 4.3.1).

NOTE For single-span systems with uniformly distributed loads, and with the connection fulfilling the requirements of 7.1.1(3), Annex B can provide the internal forces with respect to inelastic strains as defined in 3.1.3.

(2) The points in time that should be considered in design are:

t_c the time according to EN 13670:2009, 8.5 (6), when curing and protection of the concrete are completed. This is the age of concrete t_s at which drying shrinkage begins, according to EN 1992-1-1:2004, 3.1.4(6);

t_p the time of removal of the props;

t_0 the time when the concrete achieves the design strength or the time when the design imposed load is applied to the composite structure before creep and inelastic strains have taken place in concrete and timber, whichever is the earlier

t_∞ the time for design for the long-term condition, which is the final point in the service life at which creep and inelastic strains have developed fully in concrete and timber.

(3) Design at t_0 and t_∞ should be verified. The construction stage should be included in the design by superimposing the effects sustained between times t_p and t_0.

(4) Further design stages between t_0 and t_∞ (between 3 years and 7 years, for example) should be considered. The verification of these design stages may be neglected if the higher stress in the timber at t_0 or t_∞, due to the quasi-permanent combination of actions (refer to 4.2(2)), is increased by 25 % and the ultimate limit state in the timber cross-section is still satisfied.

(5) The effect of creep deformation may be considered by using the effective moduli of elasticity of concrete and timber and the effective slip modulus of the connection in accordance with 4.3.2(6).

(6) The composite action influence on the effective creep coefficient should be considered (refer to 4.3.2(6)).

(7) The composite action influence on the effective creep coefficient may be determined by use of the creep coefficient modification factors in Table 7.1 (refer to 4.3.2(6)).

Table 7.1 — Modification of creep coefficients for composite action in slab systems (where $b_{tim} = b_{conc}$ and $\frac{1}{5} < \frac{A_{conc,ef}}{A_{tim}} \leq 1$) and in beam systems (where $\frac{b_{conc,ef}}{b_{tim}} > 5$ and $1 < \frac{A_{conc,ef}}{A_{tim}} \leq 5$) [a]

	for $t = \infty$	**for t = 3 to 7 years**
Concrete, $\varphi = 3.5$:		
and $k_{def} = 0,6$	$\psi_{conc} = 2,6 - 0,8\gamma_1^{2}$	$\psi_{conc} = 2,5 - \gamma_1^{1,1}$
and $k_{def} = 0,8$	$\psi_{conc} = 2,3 - 0,5\gamma_1^{2,6}$	$\psi_{conc} = 2,2 - 0,8\gamma_1^{1,2}$
Concrete, $\varphi = 2.5$:		
and $k_{def} = 0,6$	$\psi_{conc} = 2,0 - 0,5\gamma_1^{1,9}$	$\psi_{conc} = 1,9 - 0,6\gamma_1^{1,1}$
and $k_{def} = 0,8$	$\psi_{conc} = 1,8 - 0,3\gamma_1^{2,5}$	$\psi_{conc} = 1,7 - 0,5\gamma_1^{1,1}$
Timber:		
all cases	$\psi_{tim} = 1,0$	$\psi_{tim} = 0,5$
Connection:		
all cases	$\psi_{conn} = 1,0$	$\psi_{conn} = 0,65$
NOTE For $t = 0$, the values of ψ_{conc}, ψ_{tim} and ψ_{conn} are 0.		
[a] Linear interpolation may be used for different creep coefficients of timber and concrete.		

where

b_{tim} is the width of the timber;

b_{conc} is the width of the concrete;

$A_{conc,ef}$ is the effective area of the concrete cross-section (as indicated in 7.1.1 (11));

A_{tim} is the area of the timber cross-section;

$b_{conc,ef}$ is the effective width of the concrete according to 7.1.1 (11);

t is a point in time;

ψ is the creep coefficient of the concrete;

k_{def} is the deformation factor of the timber;

ψ_{conc} is the coefficient for the effect of composite action on the creep coefficient of the concrete cross-section;

γ_1 is the composite factor of the concrete cross-section according to EN 1995-1-1:2004, Annex B, Formula (B.5), at time t_0.

ψ_{tim} is the coefficient for the effect of composite action on the creep coefficient of the timber cross-section;

ψ_{conn} is the coefficient for the effect of composite action on the creep coefficient of the connection.

(8) When methods other than the γ-method (see Annex B to EN 1995-1-1) are used, the parameter γ_1 may be expressed using Formula (7.2) provided that no external axial loads are in place.

$$\gamma_1 = \frac{E_{\mathrm{tim}} A_{\mathrm{tim}} \; E_{\mathrm{tim}} I_{\mathrm{tim}} \; N_{\mathrm{tim}}}{E_{\mathrm{conc}} A_{\mathrm{conc,ef}} \left(E_{\mathrm{tim}} A_{\mathrm{tim}} \; M_{\mathrm{tim}} \; z - E_{\mathrm{tim}} I_{\mathrm{tim}} \; N_{\mathrm{tim}} \right)} \tag{7.2}$$

where

E_{tim} is the modulus of elasticity of the timber;

A_{tim} is the area of the timber cross-section;

I_{tim} is the moment of inertia of the timber cross-section;

N_{tim} is the axial force in the timber cross-section at time t_0 obtained by structural analysis of the permanent load;

E_{conc} is the modulus of elasticity of the concrete;

$A_{\mathrm{conc,ef}}$ is the effective area of the concrete cross-section (as indicated in 7.1.1 (11));

M_{tim} is the bending moment in the timber cross-section at time t_0 obtained by structural analysis of the permanent load;

z is the distance between the centres of gravity of the cross-sections.

(9) The reduction of the effect of shrinkage of concrete due to creep may be considered when determining internal forces using the Formulae (7.3) to (7.5):

$$\varepsilon_{\mathrm{ef,conc}} \left(t = t_0 \right) = 0 \tag{7.3}$$

$$\varepsilon_{\mathrm{ef,conc}} \left(t = 3 \text{ to} 7 \text{ years} \right) = 0{,}6 \; \varepsilon_{\mathrm{conc}} \tag{7.4}$$

$$\varepsilon_{\mathrm{ef,conc}} \left(t = \infty \right) = 0{,}9 \; \varepsilon_{\mathrm{conc}} \tag{7.5}$$

where

$\varepsilon_{\mathrm{ef,conc}}$ is the effective shrinkage of concrete for the consideration in the design;

t is a point in time;

$\varepsilon_{\mathrm{conc}}$ is the end value of shrinkage of concrete according to EN 1992-1-1.

7.2 Propping

(1) The effects of the construction sequence may be disregarded when the timber is effectively propped during concrete placement, with the props left in place until the concrete attains the required compressive strength.

NOTE Propping can be regarded as effective when the maximum stress induced in timber due to the weight of fresh concrete does not exceed 10 % of the design bending strength of the timber associated with the duration of propping.

(2) If propping cannot be considered effective or the timber beam is left unpropped during concrete placement, the increased weight of the concrete slab due to the deflection of the timber beam caused by the weight of the fresh concrete should be considered.

(3) In a propped structure, the stress distributions due to the effect of concrete shrinkage before the removal of props can cause cracking of the concrete slab and should be considered in the design. This may be achieved by disregarding the tensile strength of the concrete.

8 Ultimate limit states

8.1 General

(1) Except where stated in this standard, the concrete part should be designed in accordance with EN 1992-1-1 and EN 1994-1-1 where relevant.

(2) Except where stated in this standard, the timber part should be designed in accordance with EN 1995-1-1.

8.2 Beams and slabs – Verification of cross-sections

8.2.1 Verification of timber

(1) The timber part shall be verified according to EN 1995-1-1.

8.2.2 Verification of concrete

(1) Formulae (8.1) and (8.2) should be satisfied:

— Compression

$$\sigma_{\text{conc,c,d}} \leq f_{\text{cd}} \tag{8.1}$$

— Tension

$$\sigma_{\text{conc,t,d}} \leq f_{\text{ctd}} \tag{8.2}$$

where

$\sigma_{\text{conc,c,d}}$ is the design compressive stress in the concrete member (> 0) caused by axial force and bending;

f_{cd} is the design compressive strength of concrete according to EN 1992-1-1:2004, 3.1.6 (1);

$\sigma_{\text{conc,t,d}}$ is the design tensile stress in the concrete member (> 0) caused by axial force and bending;

f_{ctd} is the design tensile strength of concrete; according to EN 1992-1-1:2004, 3.1.6 (2).

(2) If Formula (8.2) is not satisfied, verification should include concrete cracking as shown in Clause 7.

8.2.3 Verification of connections

(1) The maximum load on individual connections should be limited by the load-carrying capacity $F_{v,Rd}$, see Formula (8.3):

$$\frac{F_{v,Ed}}{F_{v,Rd}} \leq 1 \tag{8.3}$$

where

$F_{v,Ed}$ is the design shear force per connection;

$F_{v,Rd}$ is the design load-carrying capacity per connection.

(2) The characteristic load-carrying capacity of a connection $F_{v,Rk}$ should be determined according to Clause 10. $F_{v,Rd}$ should be calculated from $F_{v,Rk}$ in accordance with 4.4.2(5). All design strengths for timber and concrete should be determined according to Clause 5.

8.2.4 Verification of concrete for in-plane shear (including diaphragm actions)

(1) To prevent premature longitudinal shear failure or longitudinal splitting, transverse reinforcement in the slab should be designed for the ultimate limit state and a minimum amount of reinforcement should be provided, as specified in 9.4.2.

(2) The design longitudinal shear stress for any potential surface of longitudinal shear failure within the slab τ_{Ed} should not exceed the design longitudinal shear strength of the shear surface considered. In the case of higher level of shear stresses, EN 1992-1-1:2004, 6.5 or EN 1992-1-1:2004, Annex F should be applied.

(3) For each type of shear surface considered, the design longitudinal shear stress τ_{Ed} should be determined from the design longitudinal shear over a certain length of beam ΔF_d, taking into account the number of shear planes and the length of the shear surface.

(4) According to EN 1992-1-1:2004, 6.2.4, the design longitudinal shear stress in the concrete flange (shear planes a-a in Figure 8.1) τ_{Ed} should be determined by Formula (8.4):

$$\tau_{Ed} = \frac{\Delta F_d}{h_f \ \Delta x} \tag{8.4}$$

where

τ_{Ed} is the design longitudinal shear stress for verification of concrete for in-plane shear;

ΔF_d is the design longitudinal shear over a certain length of beam;

h_f is the thickness of the concrete flange;

Δx is the length under consideration, which can be taken as 1 000 mm. The maximum value that may be assumed for Δx is half the distance between the section where the moment is 0 and the section where the moment is maximum. Where point loads are applied, the length Δx should not exceed the distance between point loads.

(5) For a shear surface passing around the shear connectors (shear planes b-b in Figure 8.1), the design longitudinal shear stress may be determined by Formula (8.5):

$$\tau_{\mathrm{Ed}} = \frac{2\,\Delta F_{\mathrm{d}}}{l_{\mathrm{shear}}\,\Delta x} \tag{8.5}$$

where

l_{shear} is the length of the shear surface around the shear connectors.

(6) The length of the shear surface l_{shear} should be determined by Formulae (8.6) and (8.7):

— for a single or staggered row of fasteners

$$l_{\mathrm{shear}} = 2\,h_{\mathrm{sc}} + d_{\mathrm{sc}} \tag{8.6}$$

— for fasteners arranged in pairs

$$l_{\mathrm{shear}} = 2\,h_{\mathrm{sc}} + s_{\mathrm{t}} + d_{\mathrm{sc}} \tag{8.7}$$

where

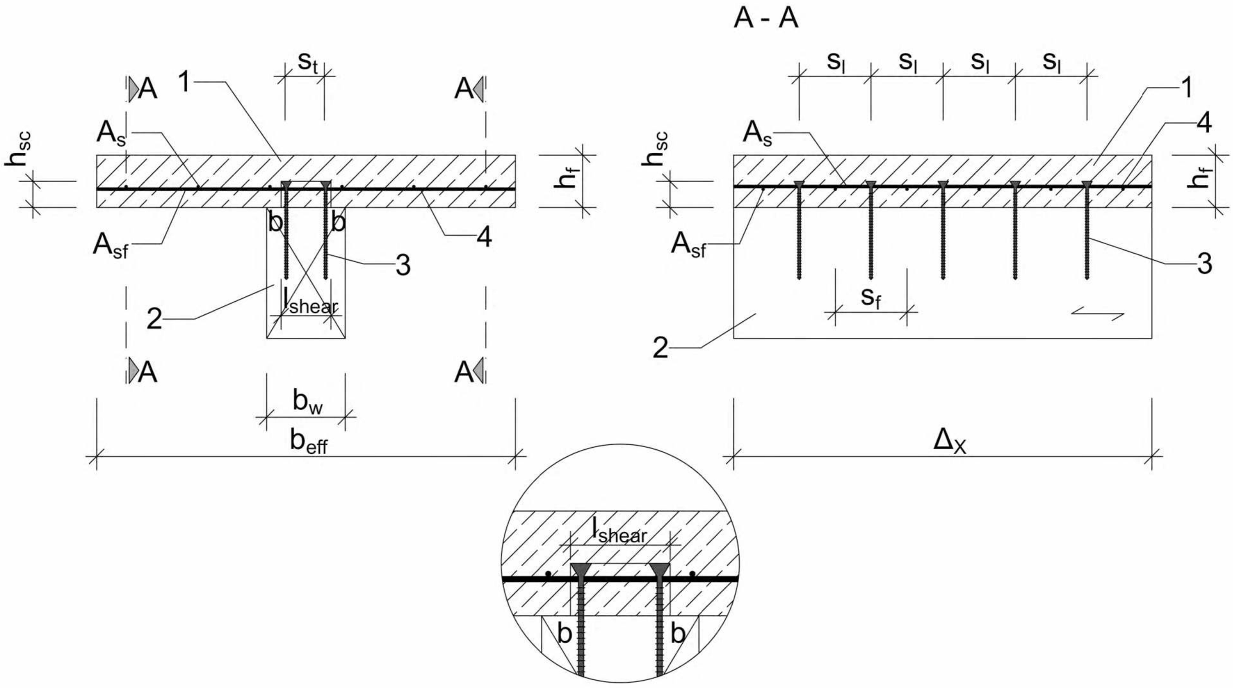
h_{sc} is the height of the fastener in the concrete;

d_{sc} is the diameter of the fastener in the concrete;

s_{t} is the transverse centre-to-centre spacing of the fasteners.

(7) The design shear strength of the concrete flange (shear planes a-a in Figure 8.1) should be determined in accordance with EN 1992-1-1:2004, 6.2.4, where the shear strength of the flange may be calculated by considering the flange as a system of compressive struts combined with ties for tensile reinforcement. The transverse reinforcement per unit length $A_{\mathrm{sf}} / s_{\mathrm{f}}$ may be determined by Formula (8.8):

$$\frac{A_{\mathrm{sf}}}{s_{\mathrm{f}}} = \frac{\Delta F_{\mathrm{d}}}{\Delta x\, f_{\mathrm{yd}}\, \cot\theta} \tag{8.8}$$



Key

1 concrete

2 timber

3 fastener

4 reinforcement steel

Figure 8.1 — The connection between flange and web

where

A_{sf}	is the cross-sectional area of the transverse reinforcement of the flange per unit length;
s_f	is the spacing of the transverse reinforcement bars in the concrete slab;
ΔF_d	is the design longitudinal shear over a certain length of beam;
Δx	is the length under consideration;
f_{yd}	is the design value of the yield strength of steel reinforcement;
θ	is the angle of the concrete strut.

(8) To prevent crushing of the compression struts in the flange, the condition in Formula (8.9) should be satisfied:

$$\sigma_{c,d} = \tau_{Ed} \left(\cot\theta + \tan\theta\right) < \nu f_{cd} \tag{8.9}$$

where

$\sigma_{c,d}$ is the design compressive stress in the concrete strut;

τ_{Ed} is the design longitudinal shear stress given in 8.2.4 (4);

θ is the angle of the concrete strut;

ν is the strength reduction factor for concrete cracked in shear or other actions given in EN 1992-1-1:2004, 6.2.5, refer to Formula (10.14);

f_{cd} is the design compressive strength of the concrete.

(9) For a shear surface passing around the shear connectors (e.g. shear surface b-b in Figure 8.1.), the design shear strength of the concrete flange should satisfy the condition in Formula (8.10):

$$\sigma_{c,d} = \tau_{Ed} < \nu f_{cd} \tag{8.10}$$

where

$\sigma_{c,d}$ is the design compressive stress in the concrete strut;

τ_{Ed} is the design longitudinal shear stress given in 8.2.4 (4);

ν is the strength reduction factor for concrete cracked in shear or other actions given in EN 1992-1-1:2004, 6.2.5;

f_{cd} is the design compressive strength of the concrete.

Additional information may be found EN 1992-4 for fasteners loaded in shear.

(10) Where a combination of pre-cast elements and in-situ concrete is used, resistance to longitudinal shear should be determined in accordance with EN 1992-1-1:2004, 6.2.5.

(11) Longitudinal tension reinforcement in the flange should be anchored beyond the strut required to transmit the force back to the web at the section where this reinforcement is required. Anchorage should be detailed in accordance with EN 1992-1-1:2004, 6.2.4 (7).

(12) The effective transverse reinforcement per unit length A_{sf} / s_f for shear surface b-b should be as shown in Figure 8.1, in which A_{sf} is the area of reinforcement per unit length of beam anchored in accordance with EN 1992-1-1:2004 , 8.4, for longitudinal reinforcement.

(13) The minimum area of reinforcement should be determined in accordance with EN 1992-1-1:2004, 12.1.1, where the maximum longitudinal spacing between shear assemblies should not exceed 150 mm. The minimum transverse reinforcement according to Table 9.1 may be assumed.

8.3 Walls

(1) For composite vertical elements subjected to axial compression load F_c acting at the geometric centroid, verification of load-carrying capacity may be in accordance with EN 1995-1-1:2004, Annex C, C.1.2 and EN 1992-1-1:2004, 9.6 and Annex I.

(2) Verification of the load-carrying capacity of a connection may be in accordance with EN 1995-1-1:2004, Annex B, B.5 and EN 1995-1-1:2004, Annex C, C.2.2 and EN 1992-1-1:2004, 9.6 and Annex I.

(3) In cases where small moments (e.g. from self-weight) are acting in addition to the axial load, verification of compression and bending may be carried out according to EN 1995-1-1:2004, 6.3.2(3) and EN 1992-1-1:2004, 9.6 and Annex I.

9 Serviceability limit states

9.1 General

(1) A structure with timber-concrete composite parts should be designed and constructed such that all relevant serviceability limit states are satisfied according to the principles of EN 1990.

NOTE Serviceability criteria are stated in EN 1990:2002, 3.4.

9.2 Deflection

(1) Limiting values for deflections should be taken from EN 1995-1-1.

(2) Deflections should be verified at time t_0 and at final time t_∞ in accordance with 7.1.2(3) of this document.

(3) The reference level for deflection is the upper side of the composite structure. Where the deflection can impair the appearance of the building, the reference level should be the underside of the structure.

(4) In non-effectively propped and unpropped structures, the deflection caused by the weight of the fresh concrete should be added to the total composite deflection.

NOTE See 7.2 for effective propping.

(5) Precamber may be used. The amount of precamber should be calculated by means of a realistic estimate of the deflection, which depends on:

— Variability of moduli of elasticity of the materials;

— Tolerances;

— Variation in the depth of the concrete due to uneven distribution of fresh concrete resulting from the precamber;

— Long-term creep and shrinkage.

(6) In buildings, a simplified approach to precamber may be used that limits it to the instantaneous deflection of the timber under the weight of fresh concrete.

9.3 Vibration

9.3.1 General

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

(2) For limits on vibration, EN 1995-1-1:2004, 7.3 may be used where relevant.

9.3.2 Floor vibration

(1) The dynamic properties of floor beams should satisfy the criteria of EN 1990:2002, Annex A, 1.4.4.

(2) For floors, a modal damping ratio of $\zeta = 0,025$ (i.e. 2,5 %) should be used for timber-concrete composite slabs alone and $\zeta = 0,035$ for slabs with floating screed, unless other values are proven to be more appropriate.

(3) The instantaneous elastic bending stiffness of the composite structure should be used in vibration analysis.

9.4 Cracking of concrete

9.4.1 General

(1) Cracking of concrete should be taken into consideration according to 7.1.1(9) and 7.1.1(10) of this document.

(2) Cracking of concrete may be controlled by limiting the calculated crack width w_k according to EN 1992-1-1:2004, Table 7.1N. The limit may be met either by satisfying the rules EN 1992-1-1:2004, 7.3.3, or by direct calculation of w_k using EN 1992-1-1:2004 , 7.3.4.

According to EN 1992-1-1:2004, Table 7.1N, maximum crack widths should be:

— For indoor elements

$$w_{max} = 0,4 \text{ mm} \quad (9.1)$$

— For external elements

$$w_{max} = 0,3 \text{ mm} \quad (9.2)$$

9.4.2 Minimum reinforcement

As an alternative to calculation, cracking may be controlled using minimum areas of reinforcement in accordance with EN 1992-1-1:2004, 7.3.2, alternatively with EN 1994-1-1:2004, 7.4.2 or Table 9.1.

Table 9.1 — Minimum reinforcement to control concrete cracking without crack width calculation

A_{req} [cm²/m']
REBAR DIAMETER [mm] / AXIAL DISTANCE [mm]

CONCRETE CLASS	RC DECK THICKNESS [cm]																	
	5		6		7		8		10		12		14		16		18	
C 12/15	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,90	Ø5/150	1,03	Ø5/150	1,16	Ø5/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150
C 16/20	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,92	Ø5/150	1,07	Ø5/150	1,22	Ø5/150	1,37	Ø6/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150
C 20/25	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,88	Ø5/150	1,06	Ø5/150	1,24	Ø5/150	1,41	Ø6/150	1,59	Ø6/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150
C 25/30	[a]0,80	Ø5/150	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,84	Ø5/150	1,04	Ø5/150	1,25	Ø5/150	1,46	Ø6/150	1,67	Ø6/150	1,88	Ø7/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150
C 30/37	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,82	Ø5/150	0,93	Ø5/150	1,16	Ø5/150	1,40	Ø6/150	1,63	Ø6/150	1,86	Ø6/150	2,09	Ø7/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø6/150		Ø7/150
C 35/45	[a]0,80	Ø5/150	[a]0,80	Ø5/150	0,90	Ø5/150	1,03	Ø5/150	1,28	Ø5/150	1,54	Ø6/150	1,80	Ø6/150	2,05	Ø7/150	2,31	Ø7/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150
C 40/50	[a]0,80	Ø5/150	0,84	Ø5/150	0,98	Ø5/150	1,12	Ø5/150	1,40	Ø6/150	1,68	Ø6/150	1,96	Ø7/150	2,24	Ø7/150	2,52	Ø7/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150		Ø7/150
C 45/55	[a]0,80	Ø5/150	0,92	Ø5/150	1,07	Ø5/150	1,22	Ø5/150	1,52	Ø6/150	1,83	Ø6/150	2,13	Ø7/150	2,44	Ø7/150	2,74	Ø8/150
		Ø5/150		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150		Ø8/150
C 50/60	0,82	Ø5/150	0,99	Ø5/150	1,15	Ø5/150	1,32	Ø6/150	1,64	Ø6/150	1,97	Ø7/150	2,30	Ø7/150	2,63	Ø8/150	2,96	Ø8/150
		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150		Ø8/150		Ø8/150
C 55/67	0,84	Ø5/150	1,01	Ø5/150	1,18	Ø5/150	1,35	Ø6/150	1,68	Ø6/150	2,02	Ø7/150	2,36	Ø7/150	2,69	Ø8/150	3,03	Ø8/150
		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150		Ø8/150		Ø8/150
C 60/75	0,88	Ø5/150	1,06	Ø5/150	1,24	Ø5/150	1,41	Ø6/150	1,76	Ø6/150	2,12	Ø7/150	2,47	Ø7/150	2,82	Ø8/150	3,17	Ø8/150
		Ø5/150		Ø5/150		Ø5/150		Ø6/150		Ø6/150		Ø7/150		Ø7/150		Ø8/150		Ø8/150

[a] Minimum reinforcement governed by Paragraph 11.3.3(3)

5.1,2,e

10 Connections

10.1 General

(1) Unless rules are stated in 10.3, the characteristic load-carrying capacity and stiffness of connections should be determined from tests according to testing standards, appropriate models or Technical Approvals as per 10.2.

(2) A distinction should be made between systems where the connection mainly or significantly relies on friction and systems where it may contribute to the structural performance but to a limited, inevitable degree.

NOTE Due to the contact between the materials, friction always influences the mechanical performance of timber-concrete connections.

(3) Composite systems where connections mainly or significantly rely on friction are beyond the scope of this document. Such systems may, however, be used within an appropriate framework (e.g. another Technical Specification).

(4) Provided that the fasteners are anchored adequately, the contribution of the rope effect may be considered when determining the load-carrying capacity for the connection. Anchorage in the concrete should achieve a minimum anchorage load at least as great as the withdrawal capacity from the timber. For dowels made of steel profiled reinforcing bars (rebar), these conditions may be considered satisfied if:

— the anchorage length into the concrete is designed according to EN 1992 - bends may be used;

and

— anchorage into the timber is evaluated as that of a smooth, predrilled round nail of the same nominal diameter and a hole diameter of 0,8 times the external rebar diameter.

10.2 Mechanical properties obtained from test

(1) The load-carrying capacity and stiffness of the connections should be determined from tests according to EN 1380, EN 1381, EN 26891, EN 12512, EN 1992-4.

NOTE Guidance on the experimental determination of the load-carrying capacity and stiffness of timber to concrete connections is given in Annex C.

(2) The determination of the characteristic value of a property should be as indicated in EN 14358.

10.3 Mechanical properties determined according to this Technical Specification

10.3.1 General

(1) The following Formulas and values should be used for determining the load-carrying capacity and slip modulus of connections made with dowel-type fasteners, glued-in rods and notched connections.

NOTE The rules given here for dowel-type fasteners and glued-in rods apply only to metallic fasteners.

(2) The minimum sizes and distances should ensure adequate connection performance in service.

10.3.2 Dowel-type fasteners

10.3.2.1 Slip modulus

(1) For connections made with dowel-type fasteners inserted perpendicular to the shear plane, the mean slip modulus for ultimate limit states K_u may be assumed as two-thirds of the slip modulus for serviceability limit states K_{ser}.

(2) The slip modulus for serviceability limit states K_{ser} of connections made with dowel-type fasteners inserted perpendicular to the shear plane should be determined using Formulae (10.1) and (10.2) derived from EN 1995-1-1 for steel-timber connections:

— for dowels, bolts, screws and nails (with predrilling):

$$K_{ser} = 2\frac{\rho_m^{1,5} d}{23} \tag{10.1}$$

— for nails (without predrilling):

$$K_{ser} = 2\frac{\rho_m^{1,5} d^{0,8}}{30} \tag{10.2}$$

where

K_{ser} is the slip modulus for serviceability limit states in N/mm;

ρ_m is the mean value of the timber member density in kg/m^3;

d is the fastener diameter in mm.

(3) The possible clearance of bolts in holes should be added to the slip.

(4) For regular interlayers, with stiffness perpendicular to the shear plane similar to that of timber and with thickness up to 30 mm:

— the slip modulus of connections with dowel-type fasteners may be taken as that for a similar configuration without interlayer, with a reduction of 30 %.

— In other cases where there is an intermediate non-structural layer between the timber and the concrete, the slip modulus should be determined by tests or special analysis.

10.3.2.2 Load-carrying capacity

(1) The load-carrying capacity $F_{v,Rk}$ of connections made with dowel-type fasteners should be determined using the Johansen models for timber-to-timber connections in single shear, given in EN 1995-1-1:2004, Formula (8.6). Provided that the embedment length of the fastener in the concrete member is at least three times the diameter of the fastener, the characteristic embedment strength of concrete member for evaluation of the load-carrying capacity based on the Johansen models should be according to Formula (10.3):

$$f_{c,h,2,k} = 3 f_{ck} \tag{10.3}$$

where

f_{ck} is the characteristic compressive strength of concrete determined in accordance with EN 1992-1-1.

(2) The rope effect of the dowel-type fasteners may be determined from EN 1995-1-1:2004, 8.2.2(2):

— The characteristic fastener withdrawal capacity shall be determined as indicated in EN 1995-1-1 for the timber side.

— If an interlayer is used, the rope effect contribution may be considered only when its stiffness perpendicular to the shear plane is similar to that of timber or of wood-based panels.

(3) For dowels made of rebar, the limits for the rope effect from round smooth predrilled nails should apply.

(4) For regular interlayers of stiffness perpendicular to the shear plane similar to that of timber and with thickness up to 30 mm, the load-carrying capacity of connections with dowel-type fasteners may be estimated on the basis of a similar configuration without interlayer with a reduction of 30 %. In other cases, where there is an intermediate non-structural layer between the timber and the concrete (e.g. formwork), the load-carrying capacity should be determined by tests or special analysis.

10.3.2.3 Detailing, sizes and distances

(1) The minimum spacing and edge distances stated in EN 1995-1-1 should be used for connections made with dowel-type fasteners.

10.3.3 Steel rebar glued into timber perpendicular to the shear plane

10.3.3.1 Slip modulus

(1) For connections made with steel rebar glued into timber perpendicular to the shear plane using epoxy resin according to an existing European Approval:

— The mean slip modulus for ultimate limit states K_u may be taken as two-thirds of the slip modulus for serviceability limit states K_{ser}.

— The slip modulus for serviceability limit states K_{ser} should be determined according to Formula (10.4):

$$K_{ser} = 0{,}10\, E_{tim}\, d \quad (10.4)$$

where

E_{tim} is the mean modulus of elasticity of timber parallel to the grain in N/mm²;

d is the nominal diameter of the rebar in mm.

10.3.3.2 Load-carrying capacity

(1) The load-carrying capacity of connections made with steel rebar glued into the timber perpendicular to the shear plane using epoxy resin or two-component polyurethane adhesive according to an existing European Approval and loaded in shear should be determined using the Johansen models for timber-to-timber connections, given in EN 1995-1-1:2004, Clause 8. The embedment strength of timber may be multiplied by the ratio between the hole diameter on the timber side and the nominal fastener diameter.

(2) Provided that the embedment length of the fastener in the concrete member is at least three times the diameter of the fastener, the embedment strength of concrete to be used in the Johansen models should be calculated as indicated in 10.3.2.2 (1).

(3) Provided that the rebar is anchored effectively in the concrete slab in accordance with 10.1(5), the rope effect may be considered but should be limited to 100 % of the Johansen part.

10.3.3.3 Detailing, sizes and distances

(1) For connections made with steel rebar glued into the timber beam perpendicular to the shear plane using epoxy resin or two-component polyurethane adhesive according to an existing European Approval and loaded in shear:

— minimum spacing and edge distances stated in EN 1995-1-1 should be used;

— the minimum glued length in mm in the timber beam should be $10d$ but at least $0,5d^2$;

where

d is the nominal diameter of the rebar in mm.

— The diameter of the hole for glued rebars should be the nominal diameter of the rebar plus no less than 2 mm and no more than twice the maximum bond line thickness of the adhesive used according to an existing European Approval.

10.3.4 Notched connections

10.3.4.1 General

(1) Provided that the following size, dimension and minimum material requirements are satisfied, the slip modulus and load-carrying capacity for notched connections may be determined as indicated in 10.3.4.2 and 10.3.4.3, respectively.

(2) Minimum sizes and distances as shown in Figure 10.2 are as follows:

— For the depth of the notch, the following should apply:

$$h_\mathrm{n} \geq \begin{cases} 20\ mm\ \ for\ normal\ loads & \text{(e.g. residential building applications)} \\ 30\ mm\ \ for\ heavy\ loads & \text{(e.g. category D from ([EN 1991-1-1:2002, Table 6.1])} \end{cases} \quad (10.5)$$

— For the length of the notch:

$$l_n \geq 150\ mm \quad (10.6)$$

— For the length of timber in front of the notch:

$$l_v \geq 12,5h_n \quad (10.7)$$

— For the distance between the notches:

$$l_s \geq 12,5h_n \quad (10.8)$$

— For the diameter of the fastener:

$$d \geq 6mm \quad (10.9)$$

— For the angle of the notch, see Figure 10.2:

$$80° \leq \alpha \leq \min\{115°; 90° + \theta\} \tag{10.10}$$

(3) Minimum material requirements are:

For concrete:

— strength class C20/25 or higher according to EN 1992-1-1;

— Maximum concrete aggregate diameter:

$$d_g \leq 16 \text{ mm} \tag{10.11}$$

For timber:

— Glulam strength GL24h or higher according to EN 14080;

— Softwood strength class C24 or higher according to EN 338; or

— Laminated veneer lumber compliant with EN 14374

10.3.4.2 Slip modulus

(1) For notched connections, the mean slip modulus for ultimate limit states K_u may be assumed to be equal to the slip modulus for serviceability limit states K_{ser}.

$$K_{ser} = \begin{cases} 1\,000 \frac{\text{N/mm}}{\text{mm}} & \text{for } h_n = 20 \text{ mm} \\ 1\,500 \frac{\text{N/mm}}{\text{mm}} & \text{for } h_n \geq 30 \text{ mm} \end{cases} \tag{10.12}$$

where

h_n is the depth of the notch according to Figure 10.2.

(2) Linear interpolation may be used for h_n between 20 mm and 30 mm.

10.3.4.3 Load-carrying capacity

(1) The criterion in Formula (10.13) shall be fulfilled:

$$F_{v,Ed} \leq F_{Rd} \tag{10.13}$$

where

$F_{v,Ed}$ is the design shear force between the timber and the concrete cross-section;

F_{Rd} is the design load-carrying capacity for the notched connection.

(2) The load-carrying capacity values F_{Rd} for notched connections should be taken as the minimum value found from the capacities determined for the various failure modes shown in Figure 10.1 in accordance with Formulae (10.4) to (10.17):

$$F_{\mathrm{Rd}} = \min \begin{cases} f_{\mathrm{vcd}}\, b_{\mathrm{n}}\, l_{\mathrm{n}} & \text{a) shear of concrete} \\ f_{\mathrm{cd}}\, b_{\mathrm{n}}\, h_{\mathrm{n}} & \text{b) crushing of concrete} \\ k_{\mathrm{cr}}\, f_{\mathrm{v,t,d}}\, b_{\mathrm{n}}\, l_{\mathrm{min}} & \text{c) shear of timber} \\ f_{\mathrm{c,0,d}}\, b_{\mathrm{n}}\, h_{\mathrm{n}} & \text{d) crushing of timber} \end{cases} \tag{10.14}$$

with

$$l_{\mathrm{min}} = 8\, h_{\mathrm{n}} \tag{10.15}$$

$$f_{\mathrm{vcd}} = \frac{\nu\, f_{\mathrm{cd}}}{\left(\cot\theta + \tan\theta\right)} \tag{10.16}$$

$$\nu = 0{,}6\left(1 - \frac{f_{\mathrm{ck}}}{250}\right) \tag{10.17}$$

where

f_{vcd} is the effective design shear strength of the concrete member;

b_{n} is the notch width;

l_{n} is the notch length, see Figure 10.2;

f_{cd} is the design compressive strength of the concrete member;

h_{n} is the notch depth, see Figure 10.2;

k_{cr} is the crack factor and may be obtained from EN 1995-1-1;

$f_{\mathrm{v,t,d}}$ is the design shear strength of the timber member;

l_{min} is the minimal shear length of the timber;

$f_{c,0,d}$ is the design compression strength of the timber member parallel to the grain;

l_{v} is the length of timber in front of the end notch, see Figure 10.2;

l_{s} is the distance between notches, see Figure 10.2;

ν is a strength reduction factor for concrete cracked in shear;

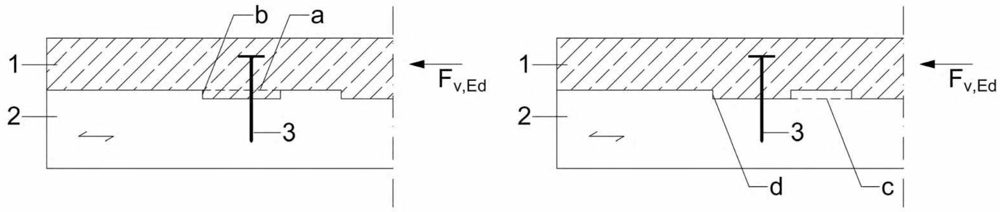
θ is the angle of the concrete strut between the maximum values given in EN 1992-1-1 and the minimum value of Formula (10.18):

$$\theta = \max\left\{\arctan\frac{0{,}5\left(h_c + h_n\right)}{\left(l_n + l_s\right)};\arctan\frac{h_n}{l_n}\right\} \tag{10.18}$$

f_{ck} is the characteristic compressive strength of the concrete member;

h_{c} is the height of the concrete without the depth of the notch, see Figure 10.2.

NOTE The design values of the timber material properties are determined using k_{mod}.



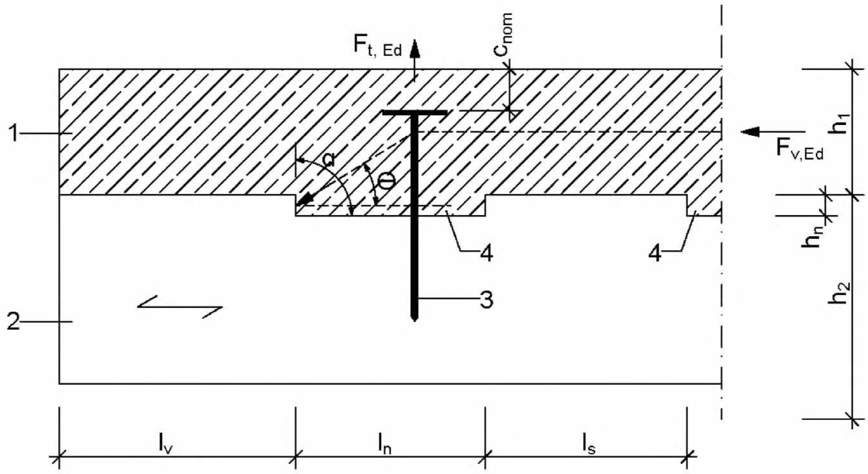
Key

1 concrete

2 timber

3 fastener loaded axially

Figure 10.1 — Notched connection failure modes



Key

1 concrete

2 timber

3 fastener loaded axially

4 notch

Figure 10.2 — Notched connection dimensions

(3) Unless more detailed analytical models are available, notched connections should be designed for a minimum vertical component $F_{t,Ed}$ in Figure 10.2, given by Formula (10.19).

$$F_{t,Ed} = max\left(F_{v,Ed} \tan\theta; 0,1F_{v,Ed}\right) \quad (10.19)$$

where

$F_{t,Ed}$ is the design tensile force between the timber and the concrete cross-section;

$F_{v,Ed}$ is the design shear force between the timber and the concrete cross-section.

(4) The position of the fastener should be based on the angle θ.

10.4 Detailing

10.4.1 General

(1) All composite timber members shall have a minimum of four connections distributed along the span. In composite members with a span of less than 2 metres, the number may be reduced to a minimum of two fasteners. In a system with planar timber elements (for example CLT), the same requirements shall apply per metre transverse to the span.

10.4.2 Minimum tensile force between the timber and the concrete

(1) Unless more detailed analytical models are available, to prevent separation of the slab, connections shall be designed to resist a tensile force between the timber and the concrete. The minimum design value of this force for simply supported beams may be determined from Formula (10.20):

$$F_{t,Ed} = 0,1F_{v,Ed} \quad (10.20)$$

where

$F_{t,Ed}$ is the design tensile force between the timber and the concrete cross-section;

$F_{v,Ed}$ is the design shear force between the timber and the concrete cross-section.

(2) For other than discrete connection systems, the tensile force between the timber and the concrete should be determined using verified models, with a minimum value given by Formula (10.20).

11 Detailing and execution

11.1 General

(1) 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 (see EN 1995-1-1:2004, 10.2(3)).

(2) Timber with fissures that can affect fastener lines should not be used.

(3) When placing fresh concrete on timber, the transfer of water between these two materials should be minimized (e.g. use of plastic sheeting, grout wash, concrete with additives, wetting the wood surface before casting).

(4) Timbers that affect the hardening of concrete (e.g. larch, due to water-soluble extractives) should not be used in direct contact with fresh concrete.

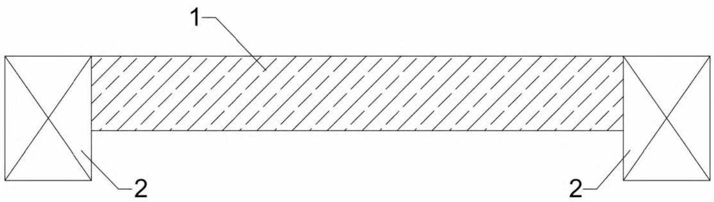
(5) If the concrete cross-section is installed between the timber beams (Figure 11.1), the stiffness of the connections shall be considered in the three directions (in the shear plane and perpendicular to the shear plane). The corresponding forces in the connection shall be taken into account, namely:

— Shear force in the span direction caused by composite action

— Shear force perpendicular to the span direction caused by local shear transfer

— Tensile force perpendicular to the connection shear plane caused by distribution of load into the concrete slab

For the design of the concrete and the connections, EN 1992-1-1:2004 and EN 1994-2:2005, 6.6.4 shall apply.



Key

1 concrete slab between timber beams

2 timber beam

Figure 11.1 — Example of a concrete cross-section between timber beams

11.2 Detailing of the cross-section

(1) The minimum thickness of the concrete slab should be 50 mm. The maximum thickness should be 300 mm.

(2) The thickness of the intermediate layer, when connections made with dowel-type fasteners perpendicular to the grain are used, should not exceed 50 mm.

(3) The support of the timber-concrete-composite structure should ensure that there is no tension perpendicular to the interface unless special analyses are performed.

NOTE When the support is on the lower cross-section, there is no tension force perpendicular to the interface.

11.3 Detailing of the shear connection and influence of execution

11.3.1 Resistance to separation

(1) Fasteners should be anchored in the upper (compression) part of the concrete slab.

11.3.2 Cover and concreting for buildings

(1) Concrete cover over the reinforcement should fulfil the requirements of EN 1992-1-1.

(2) The detailing of shear connections should allow concrete to be consolidated properly around the base of the fastener.

(3) If cover over the fasteners is required for durability, the nominal concrete cover of the fastener c_{nom} should be:

$$c_{nom} \geq \max\left\{20\,\text{mm};\ c_{min,dur} + 5\,\text{mm}\right\} \quad (11.1)$$

where

$c_{min,\ dur}$ is the minimum cover of the reinforcement steel according to EN 1992-1-1:2004, Table 4.4.

(4) If cover is not required for durability, the tops of the fasteners may be flush with the upper surface of the concrete slab.

(5) The rate and sequence of concrete placement should be such that the deformation of the timber under the weight of concrete does not damage partially set concrete due to limited composite action. Wherever possible, deformation should not be imposed on a shear connection until the concrete has reached sufficient compressive strength.

(6) The maximum size of the aggregate is 20 mm; smaller may be necessary depending on the detailing (e.g. for notched connections).

11.3.3 Reinforcement in the slab

(1) Where the shear connection is adjacent to the longitudinal edge of a concrete slab, transverse reinforcement should be fully anchored in the concrete between the edge of the slab and the adjacent row of connections.

(2) At the end of a composite cantilever, sufficient local reinforcement should be provided in order to transfer forces from the shear connections to the longitudinal reinforcement.

(3) Minimum reinforcement should be 0,80 cm^2 /m in both directions, unless higher values are required for crack control, see 9.4.

(4) The reinforcement and – if there are two reinforcement layers – the lower reinforcement should be installed underneath the head or anchorage of the fastener.

NOTE The purpose of the reinforcement is to control cracking in order to maintain the integrity of the connection, and for this purpose it is most effective when placed close to the timber. A second layer of reinforcement placed closer to the top of the concrete can be used if this is required to control surface cracking.

Annex A
(informative)

Yearly variations of moisture content averaged over the timber cross-section for timber-concrete composite structures under variable environmental conditions

A.1 Use of this Annex

(1) This informative annex provides complementary / supplementary guidance to 4.4.1.2 for the determination of the yearly variation of moisture content averaged over the timber cross-section for timber-concrete composite structures under variable environmental conditions.

NOTE National choice on the application of this informative annex is given in the National Annex. If the National Annex contains no information on the application of this informative annex, it can be used.

A.2 Scope and field of application

(1) The values of the yearly variation of timber moisture content averaged over the timber cross-section given in this informative annex covers typical situations. They are not intended to be used if local conditions indicate that higher moisture content variations averaged over the timber cross-section may occur (e.g. storage of wet material, uncontrolled swimming pools, etc.).

A.3 Yearly variations of timber moisture content

(1) The yearly variation of timber moisture content Δmc averaged over the timber cross-section should be determined specifically for the building being designed.

NOTE 1 The yearly variations of timber moisture content averaged over the timber cross-section ($\Delta mc = mc_{\mathrm{max}} - mc_{\mathrm{min}}$) cause deformation and self-equilibrated stress distribution in the composite structure due to the connection between the timber beam and the concrete slab.

NOTE 2 Δmc depends on climatic conditions, heating conditions, the initial moisture content of timber after drying, the type of coating used and the sizes (minimum of either the width or twice the depth) of the timber cross-section.

(2) In the absence of more accurate data, assuming the timber section was previously dried and left uncoated, Δmc may be estimated from Table A.1 for timber sections exposed to outdoor, sheltered conditions (refer to Figure A.1 for climatic regions represented by the Köppen-Geiger climatic map of Europe [2]).

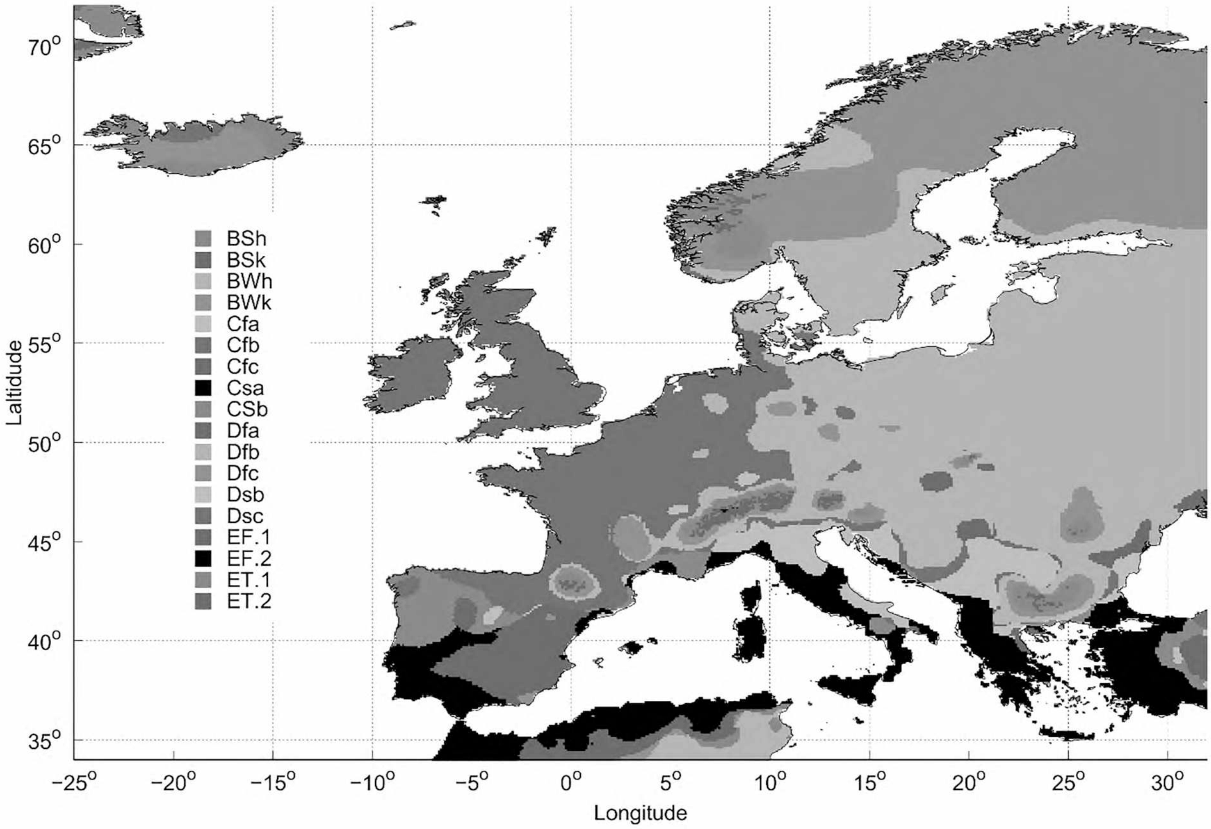


Figure A.1 — Köppen-Geiger climatic map of Europe

Table A.1 — Values of the yearly variation of timber moisture content averaged over the timber cross-section $\Delta mc = mc_{max} - mc_{min}$ as a percentage (%) for outdoor sheltered conditions

Climatic region			**Minimum of the width, or twice the depth of the timber cross-section (mm)**[a]		
Initials	**Climate**	**Cities (examples)**	**38**	**125**	**≥300**
BSK	Cold semi-arid	Madrid, Salamanca, Albacete	13,0	7,5	2,5
CSA	Warm Mediterranean	Lisbon, Cagliari, Palermo, Athens	8,0	4,0	1,0
CSB	Temperate Mediterranean	Potenza, Marsilia, Coruna, Porto	9,0	6,0	2,5
CFA	Warm oceanic	Zagreb, Milan, Bologna, Foggia	11,5	7,0	2,5
CFB	Temperate oceanic	Stuttgart, Paris, London	15,0	9,0	3,0
DFA	Warm continental	Kosice, Odessa, Zaporozhe	9,0	6,0	2,0
DFB.1	Temperate continental – Northern region	Moscow, Minsk, Vilnius, Kiev	12,0	6,0	2,0
DFB.2	Temperate continental – Southern region	Warsaw, Berlin, Munich, Prague	15,5	9,0	3,5
DFB.3	Temperate continental – Maritime region	Helsinki, Stockholm, Gothenburg, Saint Petersburg, Riga	13,5	7,5	2,5
DFC.1	Cool continental – Northern region	Rovaniemi, Inari, Luleå, Tromsø	17,5	11,5	4,0
DFC.2	Cool continental – Southern region	Tampere, Kuopio, Östersund, Ringsaker	17,5	12,0	4,0
ET	Tundra continental	Chambery, Zurich, Sofia, Gloppen	17,5	5,0	2,5

NOTE For timber cross-sections exposed to indoor, unheated conditions, the value of Δmc in Table A.1 may be reduced. The value depends on the type of building and the type of use. For typical situations, a 40 % reduction may be applied.

[a] Linear interpolation may be used for timber cross-sections of different widths.

Annex B
(informative)

Calculation of the effect of inelastic strains

B.1 Use of this Annex

(1) This informative annex provides complementary guidance to 4.3.1 for the calculation of the effect of inelastic strains.

NOTE National choice on the application of this informative annex is given in the National Annex. If the National Annex contains no information on the application of this informative annex, it can be used.

B.2 Scope and field of application

B.2.1 General

(1) This informative annex applies to inelastic strains due to concrete shrinkage, temperature variations and timber moisture content variations. The boundary conditions as the original γ-method apply, additionally the calculation is only applicable for two-layered composite structures.

B.2.2 Fictitious vertical load equivalent to inelastic strains

(1) For the fictitious vertical load which represents the inelastic strains on the structure, Formula (B.1) should be applied:

$$p_{\text{sls}} = C_{\text{p,sls}}\ \Delta\varepsilon \tag{B.1}$$

with

$$C_{\text{p,sls}} = \pi^2 \frac{E_1 A_1\ E_2 A_2\ z\ \gamma_1}{\left(E_1 A_1 + E_2 A_2\right)\ L^2} \tag{B.2}$$

$$\Delta\varepsilon = \varepsilon_2 - \varepsilon_1 \tag{B.3}$$

where

$C_{\text{p,sls}}$ is a coefficient;

$\Delta\varepsilon$ is the difference in the inelastic strain between member 1 and member 2;

E_1 is the modulus of elasticity of member 1 (e.g. concrete);

A_1 is the area of member 1 (e.g. concrete);

E_2 is the modulus of elasticity of member 2 (e.g. timber);

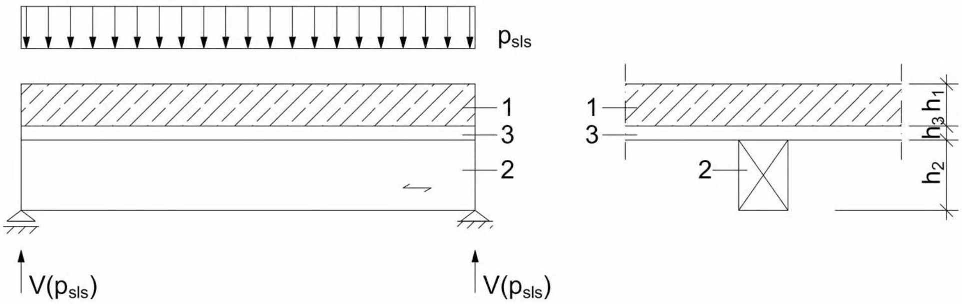
A_2 is the area of member 2 (e.g. timber);

z is the distance between the centres of gravity of the concrete slab and the timber beam;

γ_1 is a composite factor of the concrete member according to EN 1995-1-1:2004 + A1:2008 Annex B, Formula (B.5);

L is the span of the beam;

ε_{i} is the inelastic strain of member 1 or 2 caused by temperature, shrinkage or swelling (see Figure B.1).



Key

1 concrete slab

2 timber beam

3 intermediate, non-load-carrying layer

Figure B.1 — Definition of member 1 and 2

— For temperature, the inelastic strain is:

$$\varepsilon_{\mathrm{i}} = \alpha_{\mathrm{i,T}}\ \Delta T_{\mathrm{u,i,calc}} \tag{B.4}$$

where

$\alpha_{\mathrm{i,T}}$ is the coefficient of thermal expansion of member *i* (1 or 2);

$\Delta T_{\mathrm{u,i,calc}}$ is the temperature variation of member i (1 or 2) ($\Delta T_{u,i}^{+}$, $\Delta T_{u,i}^{-}$), calculated according to 4.3.1.2.

— For shrinkage/swelling of timber, the inelastic strain is:

$$\varepsilon_{2} = \alpha_{\mathrm{t,u}}\ \Delta mc_{\mathrm{calc}} \tag{B.5}$$

where

$\alpha_{\mathrm{t,u}}$ is the moisture expansion coefficient of timber parallel to the grain;

$\Delta mc_{\mathrm{calc}}$ is the moisture content variation(Δmc^{+}, Δmc^{-}, Δmc_{d}) calculated according to 4.3.1.2.

— For shrinkage of concrete, 7.1.2 (9) applies.

B.3 Effective bending stiffness

(1) The influence of the inelastic strains on the effective bending stiffness $(EI)_{ef,sls}$ should be taken into consideration by the factor $C_{J,sls}$. The effective bending stiffness for external load and inelastic strains may be determined by Formula (B.6):

$$\left(EI\right)_{\mathrm{ef,sls}} = C_{\mathrm{J,sls}}\left(EI\right)_{\mathrm{ef,EC5-AnnexB}} \tag{B.6}$$

with

$$C_{J,sls} = \frac{p_{sls} + q_d}{\frac{E_1 A_1 + E_2 A_2}{\gamma_1 E_1 A_1 + E_2 A_2} p_{sls} + q_d} \tag{B.7}$$

where

$(EI)_{ef,sls}$	is a modified effective bending stiffness according to EN 1995-1-1:2004, Annex B, which accounts for the interaction between vertical load and inelastic strains;
$(EI)_{ef,EC5-AnnexB}$	is the effective bending stiffness according to EN 1995-1-1:2004, Annex B;
$C_{J,sls}$	is a coefficient given by Formula (B.7), which relates to the interaction between vertical load q_d and inelastic strains in terms of slip in the joint;
p_{sls}	is a fictitious vertical load which represents the effects of inelastic strains on the structure, see B.3;
q_d	is the design value of the external loads;
E_1	is the modulus of elasticity of member 1 (e.g. concrete);
A_1	is the area of member 1 (e.g. concrete);
E_2	is the modulus of elasticity of member 2 (e.g. timber);
A_2	is the area of member 2 (e.g. timber);
γ_1	is the composite factor of the concrete member according to EN 1995-1-1:2004, Annex B, Formula (B.5).

In cases where $C_{J,sls}$ does not fulfil the criteria given in Formula (B.8), the bending stiffness for the external load and due to inelastic strains (concrete shrinkage; temperature variations; timber moisture content variations) should be evaluated separately. The internal forces of those effects should be superimposed.

$$0 < C_{J,sls} \begin{bmatrix} \leq 1,1 \\ \geq 0,9 \end{bmatrix} \frac{q_d + 0,8 p_{sls}}{q_d + 0,8 p_{sls} \frac{E_1 A_1 + E_2 A_2}{\gamma_1 E_1 A_1 + E_2 A_2}} \tag{B.8}$$

where

$C_{J,sls}$	is a coefficient given by Formula (B.7), which relates to the interaction between vertical load q_d and inelastic strains in terms of slip in the joint;
q_d	is the design value of the external loads;
p_{sls}	is a fictitious vertical load which represents the effects of inelastic strains on the structure;
E_1	is the modulus of elasticity of member 1 (e.g. concrete);
A_1	is the area of member 1 (e.g. concrete);

E_2 is the modulus of elasticity of member 2 (e.g. timber);

A_2 is the area of member 2 (e.g. timber);

γ_1 is the composite factor of the concrete member according to EN 1995-1-1:2004, Annex B, Formula (B.5).

B.4 Bending moment in the concrete slab (sub. 1) and the timber beam (sub. 2)

(1) Curvature is assumed to be the same in the cross-sections of both members, and the bending moment of member *i* may be calculated with Formula (B.9):

$$M_{\mathrm{i}} = \frac{(EI)_{\mathrm{i}}}{(EI)_{\mathrm{ef,sls}}} M\left(q_{\mathrm{d}} + 0,8 p_{\mathrm{sls}}\right) \tag{B.9}$$

where

$(EI)_{\mathrm{i}}$ is the bending stiffness of member *i*, namely member 1 or 2;

$(EI)_{\mathrm{ef,sls}}$ is the modified effective bending stiffness according to EN 1995-1-1:2004, Annex B, which accounts for the interaction between vertical load and inelastic strains according to Formula (B.6);

$M\left(q_{\mathrm{d}} + 0,8 p_{\mathrm{sls}}\right)$ is the resulting bending moment due to external loads and part (80 %) of the fictitious load equivalent to inelastic strains;

$M(q_{\mathrm{d}})$ is the resulting bending moment due to the external loads;

p_{sls} is a fictitious load, representing the inelastic strains according to Formula (B.1).

B.5 Axial forces

(1) The axial force in member *i* is determined by means of Formula (B.10), which achieves equilibrium:

$$N_{\mathrm{i}} = \frac{M(\mathrm{q_d}) - \sum_{i=1}^{2} M_{\mathrm{i}}}{z} \tag{B.10}$$

where

$M(q_{\mathrm{d}})$ is the resulting bending moment due to an external load only;

M_{i} is the bending moment in member *i* (namely members 1 and 2) according to Formula (B.9);

z is the distance between the centres of gravity of the concrete slab and the timber beam.

B.6 Shear force in the connection due to shrinkage

(1) The shear force due to shrinkage of the concrete slab ($\Delta\varepsilon$ > 0 according to Formula (B.3)) should be determined by Formula (B.11):

$$F_{v,Ed} = \frac{\gamma_1 \; E_1 A_1 \; a_{1\leftrightarrow c} \; s_{ef}}{(EI)_{ef,sls}} V_{max} \le F_{v,Rd} \quad \text{(B.11)}$$

with

$$V_{max} = -\pi \; E_2 A_2 \frac{E_1 I_1 + E_2 I_2}{(\gamma_1 \; E_1 A_1 + E_2 A_2) \; L \; a_{1\leftrightarrow c}} \; \Delta\varepsilon + V(q_d) \quad \text{(B.12)}$$

where

$F_{v,Ed}$	is the force on the connection;
γ_1	is the composite factor of the concrete member according to EN 1995-1-1:2004, Annex B, Formula (B.5);
E_1	is the modulus of elasticity of member 1 (e.g. concrete);
A_1	is the area of member 1 (e.g. concrete);
$a_{1\leftrightarrow c}$	is the distance from the centroid of member 1 to the centroid of the effective composite cross-section according to EN 1995-1-1:2004, Annex B, Formula (B.6);
s_{ef}	is the effective distance of the connections along the beam axis;
$(EI)_{ef,sls}$	is the effective bending stiffness according to Formula (B.6);
V_{max}	is the effective maximum shear force for determination of the forces in connection according to EN 1995-1-1:2004, Annex B, Formula B.10;
E_2	is the modulus of elasticity of member 2 (e.g. timber);
A_2	is the area of member 2 (e.g. timber);
I_1	is the moment of inertia of member 1 (e.g. concrete);
I_2	is the moment of inertia of member 2 (e.g. timber);
L	is the span of the beam;
$\Delta\varepsilon$	is the difference in the inelastic strains between member 2 and member 1 according to Formula (B.3);
$V(q_d)$	is the resulting shear force due to external load only.

(2) The shear force in connection $F_{v,Ed}$ due to shrinkage of a timber beam ($\Delta\varepsilon$ < 0 according to Formula (B.3)) should be determined by Formula (B.13):

$$F_{v,Ed} = K\,L\left(\frac{M_{max,2}\,z}{\pi\,E_2 I_2} - \frac{E_1 A_1 + E_2 A_2}{\pi\,E_1 A_1\,E_2 A_2}\,N_{max,2} - \frac{\Delta\varepsilon}{2}\right) \le F_{v,Rd} \quad \text{(B.13)}$$

where

K	is the stiffness of the connection;
L	is the span of the beam;
$M_{max,2}$	is the maximum bending moment in member 2 according to Formula (B.9);
z	is the distance of the centres of gravity of member 1 and 2;
E_2	is the modulus of elasticity of member 2 (e.g. timber);
I_2	is the moment of inertia of member 2 (e.g. timber);
E_1	is the modulus of elasticity of member 1 (e.g. concrete);
A_1	is the area of member 1 (e.g. concrete);
A_2	is the area of member 2 (e.g. timber);
$N_{max,2}$	is the maximum axial force in member 2 according to Formula (B.10);
$\Delta\varepsilon$	is the difference in the inelastic strains between member 2 and member 1 according to Formula (B.3);
$F_{v,Rd}$	is the design value of the load capacity of the connection.

Annex C
(informative)

Experimental determination of the load-carrying capacity and stiffness of timber to concrete connections

C.1 Use of this Annex

(1) This informative annex provides complementary guidance to 10.2 for the experimental determination of the load-carrying capacity and stiffness of timber to concrete connections.

NOTE National choice on the application of this informative annex is given in the National Annex. If the National Annex contains no information on the application of this informative annex, it can be used.

C.2 Scope and field of application

(1) This informative annex covers the experimental determination of load carrying capacity and stiffness of connections between timber based products and concrete as defined in 1.1.

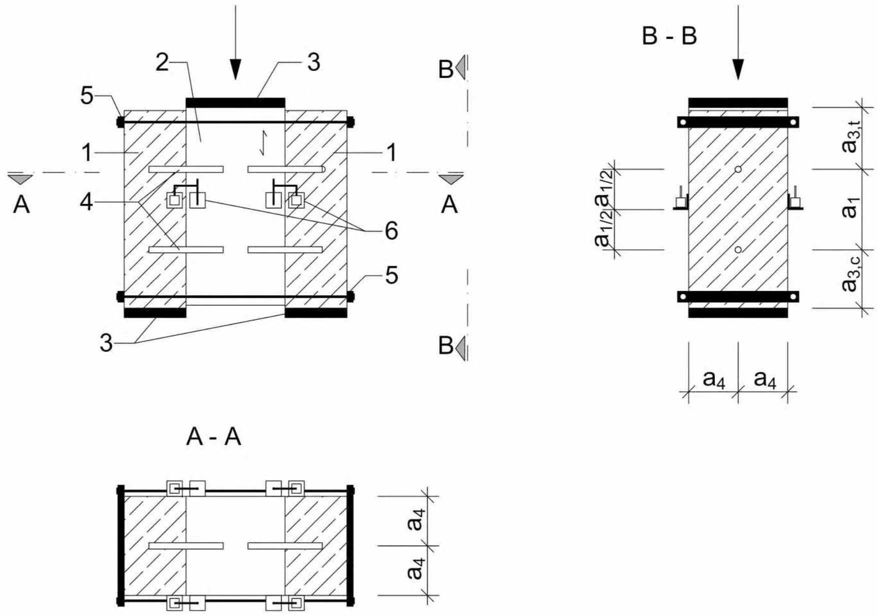
C.3 Specimen configuration

(1) Experimental assessment of connections may take place by means of double shear push-out tests.

NOTE A possible configuration for such test setup is indicated in Figure C.1.

(2) Restraints may be used to prevent separation of the concrete from the timber. In this case, the restraints should only prevent separation perpendicular to the shear plane and a prestress force that would increase friction at the timber-concrete interface should not be applied.

NOTE An example of such restraints is shown in Figure C.1.



Key

1	timber	6	displacement gauges
2	steel plate	a_1	spacing of fasteners parallel to the grain
3	concrete	$a_{3,c}$	distance between the fastener and the unloaded end
4	fasteners	$a_{3,t}$	distance between the fastener and the loaded end
5	restraints	a_4	spacing of fasteners perpendicular to the grain

Figure C.1 — Push-out test configuration

(2) For fastener connections (e.g. dowel-type fasteners, glued-in rebars, head studs, etc.), the test specimen should be prepared with at least two fasteners per shear plane. For other types of connection (e.g. notches, continuous systems, etc.), the test specimen should be designed to be representative of the performance of the system in use.

(3) Test specimen dimensions should be defined on the basis of the minimum admissible edge and spacing distances allowed for each specific fastener according to EN 1995-1-1:2004, Figure 8.7. Greater spacing may be employed in the test if it is to be used in construction.

(4) The test specimens should be produced using materials that are of a quality equal to or, provided that the failure mode does not change, lesser than those used in practice.

C.4 Testing protocol

(1) The load procedure defined in EN 26891 (ISO 6891) should be followed.

(2) The number of test specimens and the determination of characteristic values should be in accordance with EN 14358.

(3) Provided that the tests use the same or assessment methods or assessment methods equivalent to those described in this standard, tests performed in the past may be used for determination of parameters for design.

(4) Experimental values of k_{def} may be determined by applying a constant sustained load equal to 30 % of the short-term mean load-carrying capacity over an appropriate time span. This time span should be determined with consideration of climatic conditions in use and information available. The values obtained should be extrapolated to the service life of the structure.

(5) When testing is carried out, testing conditions regarding safety should be representative of the most unfavourable situation found in practice (i.e. the situation that results in lowest friction, such as placing a plastic film between the timber and the concrete or lubricating the contact face).

NOTE Friction resulting from material contact is always present in the tests, and hence it is implicitly included in determination of the mechanical properties.

C.5 Determination of mechanical properties

(1) In the experimental assessment, specified mechanical properties should include at least:

$F_{v,R,tc,k}$ the characteristic load-carrying capacity;

$K_{ser,tc}$ the mean slip modulus for serviceability;

$K_{u,tc}$ the slip modulus for ultimate limit state;

$u_{u,tc}$ the mean ultimate slip.

(2) The characteristic load-carrying capacity should be determined in accordance with EN 26891 (represented in EN 26891 as F_{max}).

(3) The mean slip modulus for serviceability limit states should be determined in accordance with EN 26891 (represented in EN 26891 as k_s).

(4) The mean slip modulus for ultimate limit states should be determined in accordance with EN 26891 as a ratio between 60 % of the estimated load-carrying capacity F_{est} and the modified slip at 60 % of the maximum load F_{max} (represented in EN 26891 as $v_{0.6,mod}$).

(5) The ultimate slip should be determined in accordance with EN 12512 (represented in EN 26891 as v_u).

(6) Specimens without reinforcement may be used as it is assumed that they will result in determination of conservative properties. When the test specimens use steel reinforcement, at least equivalent reinforcement should be adopted in the structural design.

Bibliography

[1] EN 338, *Structural timber - Strength classes*

[2] EN 1090-2, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

[3] EN 1380, *Timber structures - Test methods - Load bearing nails, screws, dowels and bolts*

[4] EN 1381, *Timber structures - Test methods - Load bearing stapled joints*

[5] EN 1991-1-5:2003, *Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions*

[6] EN 1992-4, *Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete*

[7] EN 12512, *Timber structures - Test methods - Cyclic testing of joints made with mechanical fasteners*

[8] EN 13670:2009, *Execution of concrete structures*

[9] EN 14080, *Timber structures - Glued laminated timber and glued solid timber - Requirements*

[10] EN 14358, *Timber structures - Calculation and verification of characteristic values*

[11] EN 14374, *Timber structures - Structural laminated veneer lumber - Requirements*

[12] EN 26891, *Timber structures - Joints made with mechanical fasteners - General principles for the determination of strength and deformation characteristics (ISO 6891:1983)*

[13] ISO 3898, *Bases for design of structures - Names and symbols of physical quantities and generic quantities*

[14] https://people.eng.unimelb.edu.au/mpeel/koppen.html

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