

BS EN 16351:2015



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Timber structures — Cross laminated timber — Requirements

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National foreword

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Published by BSI Standards Limited 2015

ISBN 978 0 580 76677 0

ICS 79.060.10

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2015.

Amendments/corrigenda issued since publication

Date	Text affected
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 16351

October 2015

ICS 79.060.10

English Version

**Timber structures - Cross laminated timber -
Requirements**

Structures en bois - Bois lamellé croisé - Exigences

Holzbauwerke - Brettsper Holz - Anforderungen

This European Standard was approved by CEN on 29 August 2015.

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Ref. No. EN 16351:2015 E

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European foreword

This document (EN 16351:2015) has been prepared by Technical Committee CEN/TC 124 “Timber structures”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2016, and conflicting national standards shall be withdrawn at the latest by July 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

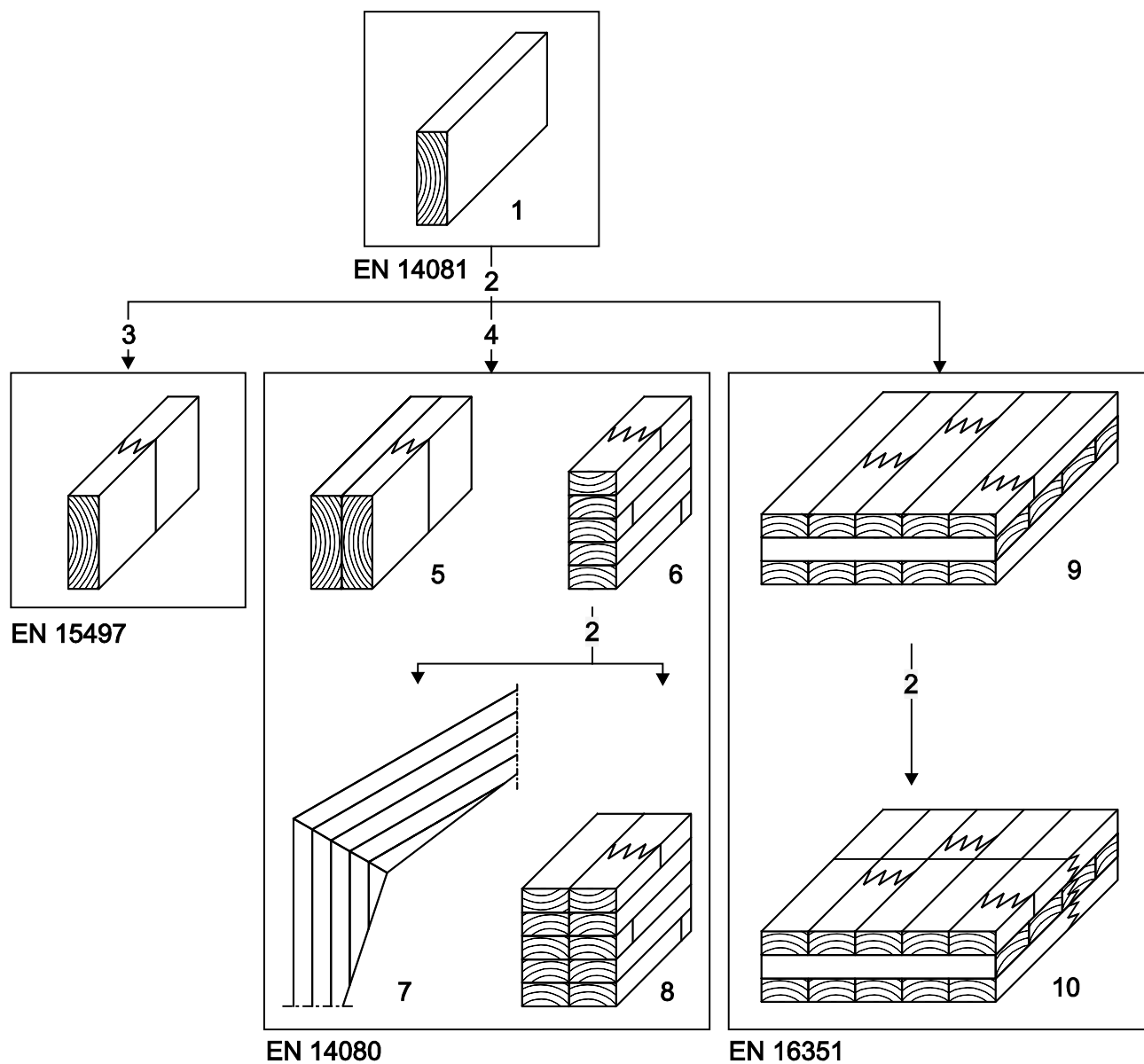
This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports basic work requirements of Regulation (EU) No 305/2011.

For relationship with the EU Regulations, see informative Annex ZA, which is an integral part of this document.

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

Introduction

Figure 1 shows the relation of European Standards prepared by CEN/TC 124.



Key

- | | | | |
|---|----------------------------------|----|---|
| 1 | boards | 6 | glued laminated timber (glulam) |
| 2 | is a component for | 7 | glulam with large finger joints |
| 3 | structural finger jointed timber | 8 | block glued glulam |
| 4 | glued laminated products | 9 | cross laminated timber (X-Lam) |
| 5 | glued solid timber | 10 | cross laminated timber (X-Lam) with large finger joints |

Figure 1 — Relation of European Standards prepared by CEN/TC 124

1 Scope

This European Standard sets out provisions regarding the performance characteristics for straight and curved structural cross laminated timber (X-Lam) both without and with large finger joints as a material for the manufacture of structural elements to be used in buildings and bridges.

This European Standard applies to cross laminated timber:

- to be used in service class 1 or 2 according to EN 1995-1-1;
- made of coniferous species and poplar listed in 5.1.5 of this standard;
- built up of at least three orthogonally bonded layers (at least two of them timber layers);
- having, depending on the number of layers, adjacent layers which may be bonded parallel to the grain;
- made of timber layers which are made of strength graded timber according to EN 14081-1;
- made of timber layers having thicknesses between 6 mm and 60 mm (including) taking into account the layup requirements given in this European standard;
- made of timber layers which may be edge bonded or which are not bonded and have spacing less than 6 mm between adjacent laminations;
- which may comprise wood based panel layers made of structural wood based panels specified in this European standard, fulfilling the requirements for use in service class 2 or 3 according to EN 1995-1-1, having no structural joints between the single panels and having thicknesses between 6 mm and 45 mm (including);
- bonded with adhesives, fulfilling the requirements given in this European standard;
- having overall thicknesses up to 500 mm;
- which is not made from reused timber or wood based panels comprising reused timber.

This European Standard also applies to cross laminated timber with large finger joints:

- made from cross laminated timber pieces having the same cross section and layup;
- made from cross laminated timber pieces having cross sectional thicknesses from 51 mm up to 345 mm (inclusive) and minimum thicknesses of the outermost layers not less than 17 mm.
- made from cross laminated timber pieces solely comprising timber layers;
- made from plane cross laminated timber pieces jointed so that no regular change between the grain directions of the layers occurs;
- with finger joints having a finger length of at least 45 mm and fingers which are visible at the two narrow sides of the components.

This European Standard applies to cross laminated timber treated against biological attack. Cross laminated timber treated with fire retardants is not covered.

It also sets out minimum production requirements and procedures for Assessment and Verification of Constancy of Performance.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 301:2013, *Adhesives, phenolic and aminoplastic, for load-bearing timber structures — Classification and performance requirements*

EN 302-1, *Adhesives for load-bearing timber structures — Test methods — Part 1: Determination of longitudinal tensile shear strength*

EN 302-2:2013, *Adhesives for load-bearing timber structures — Test methods — Part 2: Determination of resistance to delamination*

EN 302-3:2013, *Adhesives for load-bearing timber structures — Test methods — Part 3: Determination of the effect of acid damage to wood fibres by temperature and humidity cycling on the transverse tensile strength*

EN 302-4, *Adhesives for load-bearing timber structures — Test methods — Part 4: Determination of the effects of wood shrinkage on the shear strength*

EN 302-6, *Adhesives for load-bearing timber structures — Test methods — Part 6: Determination of the minimum pressing time under referenced conditions*

EN 338, *Structural timber - Strength classes*

EN 350-1, *Durability of wood and wood-based products — Natural durability of solid wood — Part 1: Guide to the principles of testing and classification of the natural durability of wood*

EN 350-2, *Durability of wood and wood-based products — Natural durability of solid wood — Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe*

EN 408, *Timber structures — Structural timber and glued laminated timber — Determination of some physical and mechanical properties*

EN 717-1, *Wood-based panels — Determination of formaldehyde release — Part 1: Formaldehyde emission by the chamber method*

EN 789:2004, *Timber structures — Test methods — Determination of mechanical properties of wood based panels*

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

EN 13183-1, *Moisture content of a piece of sawn timber — Part 1: Determination by oven dry method*

EN 13183-2, *Moisture content of a piece of sawn timber — Part 2: Estimation by electrical resistance method*

EN 13183-3, *Moisture content of a piece of sawn timber — Part 3: Estimation by capacitance method*

EN 13238, *Reaction to fire tests for building products — Conditioning procedures and general rules for selection of substrates*

EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*

EN 13823, *Reaction to fire tests for building products — Building products excluding floorings exposed to the thermal attack by a single burning item*

EN 13986, *Wood-based panels for use in construction — Characteristics, evaluation of conformity and marking*

EN 14081-1:2005+A1:2011, *Timber structures — Strength graded structural timber with rectangular cross section — Part 1: General requirements*

EN 14358, *Timber structures — Calculation of characteristic 5-percentile values and acceptance criteria for a sample*

EN 14374, *Timber structures — Structural laminated veneer lumber — Requirements*

EN 15228:2009, *Structural timber — Structural timber preservative treated against biological attack*

EN 15416-3, *Adhesives for load bearing timber structures other than phenolic and aminoplastic — Test methods — Part 3: Creep deformation test at cyclic climate conditions with specimens loaded in bending shear*

EN 15416-5, *Adhesives for load bearing timber structures other than phenolic and aminoplastic — Test methods — Part 5: Determination of conventional pressing time*

EN 15425:2008, *Adhesives — One component polyurethane for load bearing timber structures — Classification and performance requirements*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1

actual size

measured size of a cross laminated timber at a related measured/estimated moisture content

3.2

bonding strength

structural effectiveness of adhesives between timber pieces when subjected to stresses

3.3

corrected size

size of a cross laminated timber corrected by calculation from its actual size to its size at the reference moisture content

3.4

cross laminated timber

X-Lam

structural timber consisting of at least three layers of which a minimum of three are orthogonally bonded, which always comprise timber layers and may also comprise wood-based panel layers

Note 1 to entry: See also 5.2.2.7.

Note 2 to entry: Cross laminated timber in accordance with EN 16351 and multilayer solid wood panels in accordance with EN 13353 may have the same layup but the timber to be used in laminations is strength graded according to EN 14081-1 and the adhesives are tested according to 5.1.6 of this European Standard.

3.5

curved cross laminated timber

cross laminated timber having a precamber greater than 1% of the respective span

3.6

edge bonds

bonds between adjacent laminations within a timber layer

3.7

edge bonded layer

timber layer comprising structural edge bonds

3.8

finger angle

inclination α of each side of the fingers of a finger joint

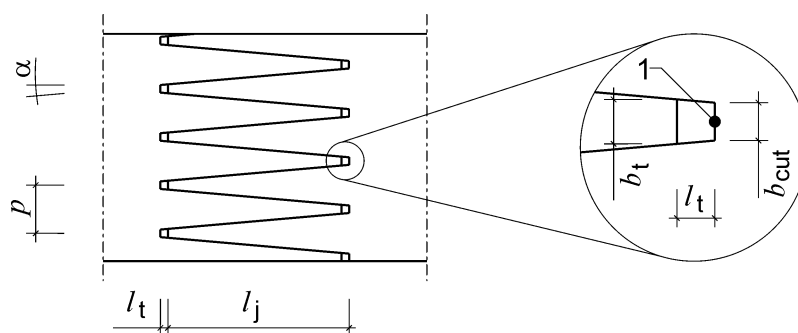
Note 1 to entry: See Figure 2.

3.9

finger joint

interlocking end joint formed by machining a number of similar, tapered, symmetrical fingers in the ends of timber components using a finger joint cutter and then bonded together

Note 1 to entry: In this European Standard the term finger joint is used for finger joints in laminations whereas finger joints between cross laminated timber are defined as large finger joints (see 3.13).



Key

l_j	finger length
p	pitch
α	finger angle
l_t	tip gap
b_{cut}	tip width of the cutter
b_t	tip width
1	slot base

Figure 2 — Typical profile of a finger joint

3.10

finger length

distance l_j between the finger base and the tip of the finger, measured along the centre line of the finger

Note 1 to entry: See Figure 2.

3.11

finished thickness

thickness after planing

3.12

laminations

structural timber boards, finger jointed unless the length of a single board matches the lamination length, being part of timber layers in cross laminated timber

3.13

large finger joint

finger joint through the full cross sectional area of two cross laminated timber pieces

Note 1 to entry: See Figure 3.

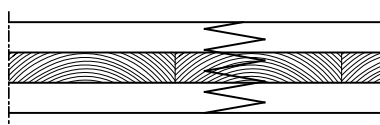


Figure 3 — Cross laminated timber with large finger joints

3.14

layup

cross sectional arrangement of timber layers or wood-based panel layers in which each layer may be made of different species and may have different strength classes, manufacturer specific strength classes or technical classes

3.15

manufacturer specific strength class

set of characteristic strength, stiffness and density properties not tabulated in a standard

3.16

maximum delamination length

largest delamination length in any single glue line measured around the circumference of the test piece

3.17

mean moisture content

mean value of the moisture content of cross laminated timber calculated from at least two measurements

Note 1 to entry: See G.3.

3.18

minimum mean density

required density at reference moisture content, estimated as the weighted mean of the mean densities of the layers, if necessary

Note 1 to entry: Minimum mean density is used for the classification of the reaction to fire.

3.19

pitch

distance between centres of adjacent finger tips

Note 1 to entry: See Figure 2.

3.20

ratio of resin to hardener

proportion of resin to hardener by mass with the resin set at 100 parts

3.21

reduction factor

ratio between tip width and pitch

Note 1 to entry: See Figure 2.

3.22

reference moisture content

moisture content at which target sizes are established

3.23

relative tip gap

ratio between tip gap and finger length

Note 1 to entry: See Figure 2.

3.24

rolling shear

shear stress for which both complementary stress components are perpendicular to the grain

3.25

target size

size specified (at the reference moisture content) to which deviations are to be related

3.26

timber layer

layer made of edge bonded or non-edge bonded timber laminations

3.27

tip gap

distance between finger-tip and slot base in a bonded finger joint

Note 1 to entry: See Figure 2.

3.28

tip width

distance between finger faces, measured at the tip of the finger

Note 1 to entry: See Figure 2.

3.29

total delamination length

sum of delamination lengths of all glue lines measured around the circumference of the test piece

3.30

wood-based panels

structural plywood, structural laminated veneer lumber (LVL) and structural solid wood panels according to EN 13986 and structural LVL according to EN 14374

3.31

wood-based panel layer

layer made of one type and technical class of wood-based panels

3.32

wood failure

rupture in or between wood fibres

3.33

wood failure percentage

percentage of the wood failure area in relation to the total sheared or split area

4 Symbols

4.1 Main symbols

A	area, in mm ² ;
A_w	area of wane, in mm ² (see Figure I.1);
a_w	length of the diagonal of wane, in mm (see Figure I.1);

b	width, in mm;
b_{cut}	tip width of the cutter (see Figure 2);
b_t	tip width, in mm (see Figure 2);
C	compression force in N (for indices see also Figures F.1 and F.2 and Tables F.1 to F.3);
d	diameter, in mm;
$\text{Delam}_{\text{max}}$	maximum delamination, in %;
$\text{Delam}_{\text{tot}}$	total delamination, in %;
e	relative tip gap;
f	strength, in N/mm ² ;
G	shear modulus, in N/mm ² ;
k	moisture deformation factor;
k_{15}	statistical factor;
l	length, in mm;
l_j	finger length, in mm (see Figure 2);
l_t	tip gap, in mm (see Figure 2);
p	pitch, in mm (see Figure 2);
M	Moment, in Nmm (for indices see also Figures F.1 and F.2 and Tables F.1 to F.3);
r	radius of curvature, in mm;
R	Resistance to forces in N or to moments in Nm (for indices see also Figures F.1 and F.2 and Tables F.1 to F.3);
t	thickness, in mm;
T	Tension force in N (for indices see also Figures F.1 and F.2 and Tables F.1 to F.3);
u	moisture content, in %;
V	Shear force in N (for indices see also Figures F.1 and F.2 and Tables F.1 to F.3);
w	deflection, in mm;
α	finger angle, in degree (see Figure 2);
ρ	density, in kg/m ³ ;
v	reduction factor of a finger joint.

4.2 Subscripts

a	actual;
c	compression;
cor	corrected;
dc	declared value;
j	properties of finger joints in laminations;
k	characteristic;
l	properties of laminations;

<i>lay</i>	properties of layers;
<i>lff</i>	properties of large finger joints;
<i>local</i>	referring to local axis or plane;
<i>m</i>	bending;
<i>mean</i>	mean value;
<i>ref</i>	reference;
<i>t</i>	tension;
<i>v</i>	shear;
<i>w</i>	property of wane;
<i>x</i>	global axis parallel to the fibre direction of the outermost layers, (see Figure F.1 and F.2);
<i>xlam</i>	properties of cross laminated timber;
<i>y</i>	global axis orthogonal to the fibre direction of the outermost layers, (see Figure F.1 and F.2);
<i>z</i>	global axis perpendicular to the plane of the cross laminated timber, (see Figure F.1 and F.2);
0	local axis parallel to the grain;
90	local axis perpendicular to the grain (both tangential and radial);
090	local plane spanned by local axis 0 and axis 90 (e.g. shear in a plane spanned by axes parallel and perpendicular to the fibre direction);
9090	local plane spanned by local axis 90 and axis 90 (e.g. shear in a plane spanned by axes perpendicular to the fibre direction).

5 Components and product characteristics, testing and assessment methods

5.1 Components characteristics

5.1.1 Timber to be used in laminations

Timber boards used in laminations shall be strength graded or tested according to EN 14081-1 and declared as tabulated strength class in accordance with EN 338, manufacturer specific strength class or as individual values.

For the determination of characteristic strengths the height factor given in EN 384 may be disregarded. The requirements of EN 14081-1 also apply to the grading of boards having thicknesses from 6 mm up to 22 mm.

Used wood is not permitted.

5.1.2 Laminations

If either the characteristic tensile strength or the characteristic bending strength of the finger joints in laminations, tested in accordance with Annex E, fulfils the requirements given in Formula (1) or (2), respectively, the properties of the laminations shall be taken as those of the timber boards:

$$f_{t,j,k} \geq f_{t,0,l,k} + 5 \text{ N/mm}^2 \quad (1)$$

$$f_{m,j,k} \geq 1,4 f_{t,0,l,k} + 8 \text{ N/mm}^2 \quad (2)$$

where:

- $f_{t,j,k}$ is the characteristic tensile strength of the finger joint in N/mm²;
 $f_{m,j,k}$ is the characteristic bending strength of the finger joint in flatwise bending in N/mm² and;
 $f_{t,0,l,k}$ is the characteristic tensile strength of the timber in N/mm².

If it is intended to manufacture preservative treated cross laminated timber, testing shall be done with finger joints in treated timber.

5.1.3 Timber layers

Each timber layer shall be made of laminations of one strength class or manufacturer specific strength class.

Each timber layer may be produced from laminations made of mixed species, if these species have similar technical properties, especially regarding swelling and shrinking.

The properties of the timber layers shall be taken as the properties of the laminations from which they are made of.

5.1.4 Wood-based panel layers

Only wood-based panels which fulfil the requirements for the use in service class 2 or 3 according to EN 1995-1-1 shall be used.

The strength of butt joints and glued joints between wood-based panels in a layer shall be regarded as zero.

Wood-based panels comprising used wood are not permitted.

The material properties of wood based panel layers shall be taken as the material properties of the wood based panels from which they are made of.

5.1.5 Species

This European Standard covers cross laminated timber made with timber laminations and wood-based panels from the following species:

Norway Spruce (*Picea abies*, PCAB), Fir (*Abies alba*, ABAL), Scots pine redwood (*Pinus sylvestris*, PNSY), Douglas fir (*Pseudotsuga menziesii*, PSMN), Western Hemlock (*Tsuga heterophylla*, TSHT), Corsican pine (*Pinus nigra Arnold subsp. laricio*, PNNL), Austrian pine (*Pinus nigra Arnold subsp. nigro*, PNNL), European Larch (*Larix decidua*, LADC), Siberian larch (*Larix sibirica*, LASI), Dahurian larch (*Larix gmelinii* (Rupr.) Kuzen.), Poplar (Applicable clones: *Populus x euramericana* cv "Robusta", "Dorskamp", "I214" and "I4551", POAL), Maritime pine (*Pinus pinaster*, PNPN), Radiata-Pine (*Pinus radiata*, PNRD), Sitka-spruce (*Picea sitchensis*, PCST), Southern Yellow pine (*Pinus palustris*, PNPL), Western Red Cedar (*Thuja plicata*, THPL), Yellow Cedar (*Chamaecyparis nootkatensis*, CHNT).

Norway spruce and Fir may be considered as one species.

NOTE 1 Letter codes according to EN 13556, if available, are given after the botanical name.

NOTE 2 Not all of the species listed above have a national grade related to a European strength class in EN 1912.

5.1.6 Adhesives for the production of cross laminated timber

5.1.6.1 General

Adhesives shall provide durable bonds in cross laminated timber.

Adhesives shall be assigned to an adhesive type (including subclasses, if relevant) according to EN 301:2013, Table 1 or EN 15425:2008, Table 1.

Taking into account the restrictions given in the referred subclauses, the following adhesive families are applicable:

- a) phenolic and aminoplastic adhesives (e.g. MF, MUF, PRF, UF) in accordance with 5.1.6.2;
- b) moisture curing one-component polyurethane adhesives (PUR) in accordance with 5.1.6.3;
- c) emulsion polymer isocyanate adhesives (EPI) in accordance with 5.1.6.4.

If a preservative treatment is done before the bonding of the laminations or layers it shall be documented that the requirements are fulfilled for the combination of the preservative and adhesive.

The applicability of an adhesive for a cross laminated timber or its components covered by this European Standard shall be taken from Table 1.

Table 1 — Applicability of adhesives for cross laminated timber and its components

	Relevant requirements for the application of:		
	Phenolic and aminoplastic adhesives	Moisture curing one-component polyurethane adhesives	Emulsion polymer isocyanate adhesives
Finger joints in laminations	5.1.6.2	5.1.6.3	5.1.6.4
Structural edge bonds between laminations	5.1.6.2	5.1.6.3	5.1.6.4
Bonds between layers	5.1.6.2	5.1.6.3	5.1.6.4
Large finger joints	5.1.6.2	5.1.6.3	Not applicable

The applicability of adhesives may be further limited by national requirements valid at the place of use.

5.1.6.2 Phenolic and aminoplastic adhesives

Phenolic and aminoplastic adhesives shall fulfil the requirements of EN 301 and shall, if required, be tested and declared according to EN 302-6.

For phenolic and aminoplastic adhesives to be used for large finger joints separate application of resin and hardener is not allowed.

5.1.6.3 Moisture curing one component polyurethane adhesives

Moisture curing one component polyurethane adhesives shall fulfil the requirements of EN 15425 and B.2 taking into account the conditions given in B.1.

The requirements given in EN 302-2:2013, 5.1, 2nd paragraph apply. For moisture curing one component polyurethane adhesives to be used in finger joints in larch wood the delamination test

according to EN 302-2 may be replaced by tests according to EN 301:2013, Annex A, with larch wood species.

Moisture curing one component polyurethane adhesives to be used for large finger joints shall fulfil the requirements of EN 15425 for glue line thicknesses up to 0,3 mm.

If required, the influence of the climate on the minimum pressing time shall be tested and declared in accordance with EN 15416-5.

5.1.6.4 Emulsion polymer isocyanate adhesives

5.1.6.4.1 General

Emulsion polymer isocyanate adhesives shall fulfil the requirements of EN 15425 and B.2 taking into account the conditions given in B.1.

If required the influence of the climate on the minimum pressing time shall be tested and declared in accordance with EN 15416-5. If the maximum glue line thickness in use is 0,2 mm these tests shall be performed with specimens having a glue line thickness of 0,2 mm.

5.1.6.4.2 Systems tested with a maximum glue line thickness of 0,3 mm

Testing according to EN 15425 and B.1 and B.2 may be done with a maximum glue line thickness of 0,3 mm instead of 0,5 mm if the glue line thicknesses in the finished cross laminated timber do not exceed 0,2 mm.

For tests with a maximum glue line thickness of 0,3 mm the requirements given in EN 15425 shall apply with the following exceptions:

- For bonding strength in longitudinal tensile strength tests according to EN 302-1 with a glue line thickness of 0,3 mm, the requirements given in Table 2 shall be met;
- For creep deformation tests with specimens loaded in bending shear according to EN 15416-3, the specimens shall have a glue line thickness of 0,2 mm.

Table 2 — Required mean shear strength in N/mm² for lap shear tests according to EN 15425 for samples glued with EPI having a glue line thickness of 0,3 mm

Treatment	Adhesive type	
	Type I	Type II
A1	9,5	9,5
A2	5,5	5,5
A3	7,6	7,6
A4	5,5	NR ^a
A5	7,6	NR ^a
A6	NR ^a	8,3
A7	7,2	NR ^a
^a Treatment cycle not required (NR).		

5.2 Characteristics of cross laminated timber

5.2.1 General

If required, characteristics of cross laminated timber shall be obtained either by testing or by determining the characteristics of the components (proxy characteristics), and declared accordingly.

For one and the same cross laminated timber some characteristics may be determined by means of proxy characteristics and others by testing.

5.2.2 Geometrical data

5.2.2.1 General

The relevant geometrical data (cross sectional sizes, layup, layer thickness and orientations, presence of grooves, presence of edge bonds and ratio of lamination width to lamination thickness shall be determined and declared.

5.2.2.2 Cross sectional sizes

The overall thickness of the cross laminated timber shall not exceed 500 mm.

5.2.2.3 Layer thickness

The finished thickness t_l of any layer shall be greater than or equal to 6 mm and less than or equal to 45 mm, except for three layered cross laminated timber where the inner timber layer may have a finished thickness up to 60 mm.

For curved cross laminated timber the maximum finished thickness t_l of the lamination is also governed by the radius r of curvature of the lamination with the smallest radius within the cross laminated timber and the characteristic bending strength of the end joints. The finished thickness t_l shall comply with Formula (3):

$$t_l \leq \frac{r}{250} \left(1 + \frac{f_{m,j,dc,k}}{80} \right) \quad (3)$$

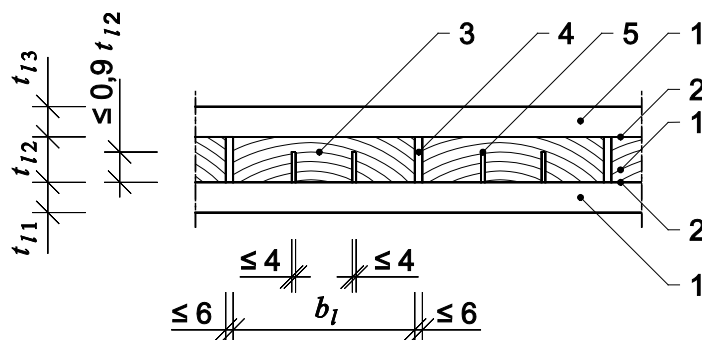
where:

- t_l is the finished lamination thickness (in mm);
- r is the radius of the lamination with the smallest radius (in mm);
- $f_{m,j,dc,k}$ is the declared characteristic bending strength of the finger joints (in N/mm²).

5.2.2.4 Grooves and edge bonds

In order to reduce cupping and cracking, laminations may be grooved. Grooves may have a maximum depth of 90 % of the thickness of the lamination and a maximum width of 4 mm, see Figure 4.

Dimensions in millimetres



Key

- 1 timber layers
- 2 bondline between layers
- 3 lamination
- 4 gap between laminations
- 5 grooves in laminations

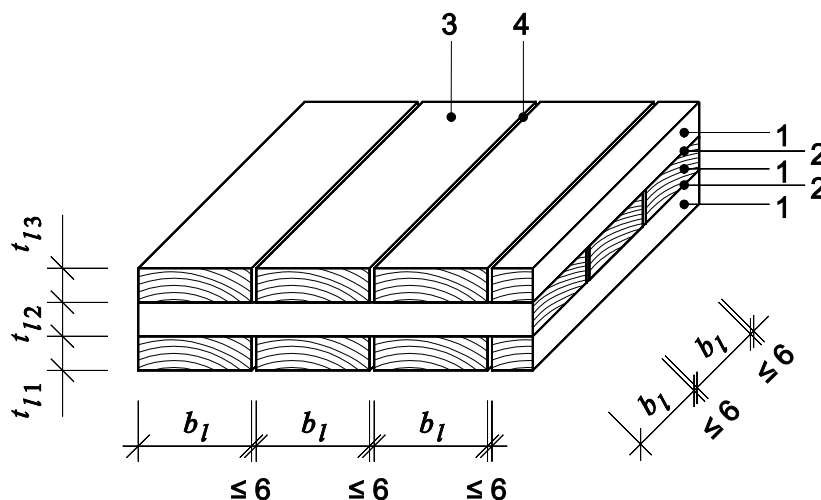
Figure 4 — Permissible geometry of grooves

Adjacent laminations may be edge bonded or non edge bonded. The width of gaps between adjacent laminations within a timber layer shall be less than or equal to 6 mm, see Figure 4.

The finished width b_l of any lamination in a non edge bonded layer, the spacings between adjacent grooves in lamellas and the distances between grooves and edges of laminations shall be greater than or equal to 40 mm. The finished width b_l of any lamination shall be less than or equal to 300 mm, see Figure 5.

If it is intended, to declare rolling shear strength according to 5.2.3.2, further limitations on the ratio of lamination width to lamination thickness apply.

Dimensions in millimetres



Key

- | | | | | |
|---|-------------------------|--------------------------|--------------------------|------------------------|
| 1 | timber layer | $6 \leq t_{1,3} \leq 45$ | $6 \leq t_{1,2} \leq 60$ | $40 \leq b_1 \leq 300$ |
| 2 | bondline between layers | | | |
| 3 | lamination | | | |
| 4 | gap between lamination | | | |

Figure 5 — Example for a layup made of three timber layers

5.2.2.5 Maximum acceptable deviations

The corrected thickness of the cross section (see 5.2.2.6) shall not deviate from the nominal thickness by more than ± 2 mm or 2 % of the nominal thickness whichever is greater.

The corrected thickness of the single layers shall not deviate from the nominal thickness by more than ± 1 mm.

5.2.2.6 Corrected sizes and moisture deformation factor

The actual sizes of cross laminated timber are influenced by swelling and shrinkage due to changes of moisture content.

The swelling and shrinkage ratios of a certain species can be regarded as constant values in the perpendicular to grain and parallel to grain directions of the timber.

If the actual moisture content differs from the reference moisture content, a corrected size is calculated from the actual size by Formula (4):

$$a_{\text{cor}} = a_a (1 + k_{\text{cor},\alpha} (u_{\text{ref}} - u_a)) \quad (4)$$

where

- a_{cor} is the corrected size, in mm;
- a_a is the actual size, in mm;
- $k_{\text{cor},\alpha}$ is the moisture deformation factor perpendicular to the grain for a change in moisture content of 1 % for moisture contents from 6 % up to 25 % (inclusive);
- $u_{\text{ref}} = 12$ % is the reference moisture content, in %;

u_a is the actual moisture content, in %, measured according to Annex G.

Unless taken from the respective design code the moisture deformation factor for unhindered moisture induced deformations and for species listed in 5.1.5 may be taken as:

$k_{\text{cor},90} = 0,002\ 4$ for deformations perpendicular to the plane;

$k_{\text{cor},0} = 0,000\ 2$ for deformations in plane.

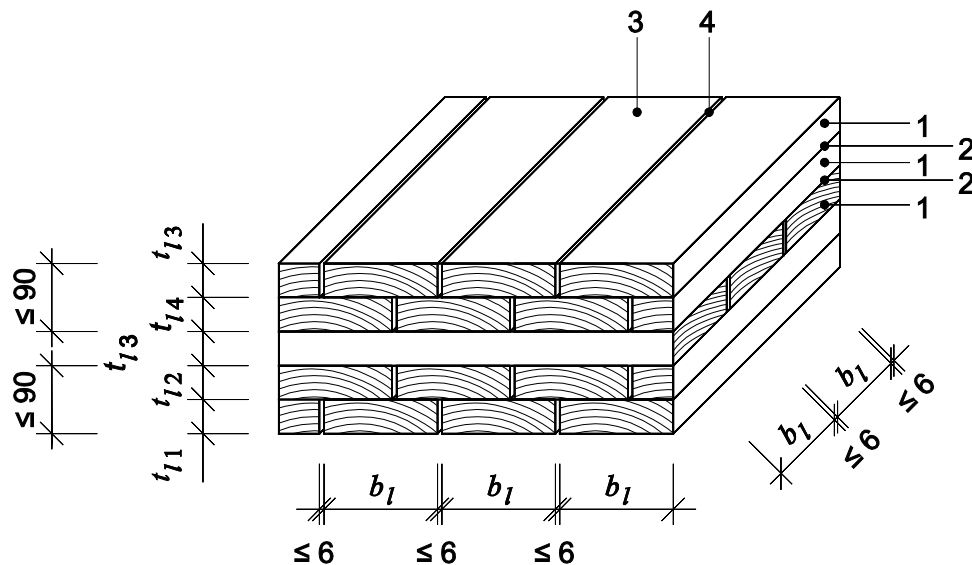
5.2.2.7 Layup (including layer orientation)

Each layup shall comprise at least three layers, at least two of them made of timber laminations. An example for a layup made of three layers is given in Figure 5.

Layers made of laminations or solid wood panels shall be orthogonally arranged, unless the following conditions are met: Within cross laminated timber made of four or more layers, up to three adjacent layers having a total thickness of not more than 90 mm may be glued parallel to the grain in the direction of one of the main axes of the cross laminated timber, see Figure 6.

The sum of the thicknesses of all wood based panel layers in a cross laminated timber may be up to 50 % of the overall thickness of the cross laminated timber, see Figure 7. Wood-based panel layers may be bonded to layers made of laminations in one of the main axis of the wood-based panels.

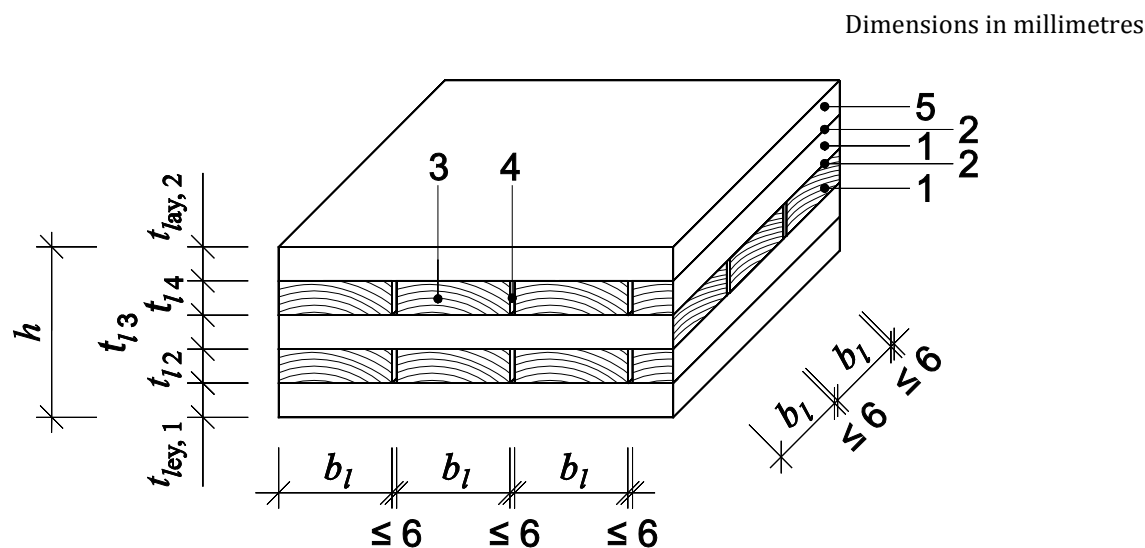
Dimensions in millimetres



Key

- 1 timber layer $6 \leq t_l \leq 45$ $40 \leq b_l \leq 300$
- 2 bondline between layers
- 3 lamination
- 4 gap between lamination

Figure 6 — Example for a layup with five timber layers outermost layers bonded parallel to the grain



Key

- | | | | |
|---|-------------------------|----------------------|-----------------------------|
| 1 | timber layer | $6 \leq t_l \leq 45$ | $40 \leq b_l \leq 300$ |
| 2 | bondline between layers | | |
| 3 | lamination | | |
| 4 | gap between lamination | | |
| 5 | wood-based panel layer | $t_{lay} \leq 45$ | $\sum_i t_{lay} \leq 0,5 h$ |

Figure 7 — Example for a layup including wood-based panels

5.2.3 Strength and stiffness properties of cross laminated timber

5.2.3.1 General

For the purpose of this standard, modulus of elasticity, bending strength, compressive strength, tensile strength and shear strength of cross laminated timber are treated as “Strength and stiffness properties of cross laminated timber” and shall be obtained either:

- by determination and declaration of geometrical data and relevant properties of the layers (proxy characteristics) according to 5.2.3.2;
- by testing of cross laminated timber and declaration of geometrical data and relevant recalculated properties of the layers determined from tests (proxy characteristics) according to 5.2.3.3.

NOTE Resistances and stiffnesses of cross laminated timber can be calculated later under a structural design for a specific end-use situation, using calculation method(s) applicable in the market where it is intended to be used.

For one cross laminated timber some properties may be verified by determination and others by testing.

5.2.3.2 Determination from geometrical data and layer's properties

If the strength and stiffness properties of the cross laminated timber are expressed as geometrical data and layer's properties the following information shall be given:

- geometrical data (cross sectional sizes, layer thicknesses and orientations, grooves (if relevant), presence of edge bonds (if relevant) and ratio of lamination width to lamination thickness according to 5.2.2);
- strength, stiffness and density properties of timber layers according to 5.1.3 and wood based panel layers according to 5.1.4, if relevant, and;
- bending strength(s) of the large finger joints according to 5.2.4, if relevant.

For cross laminated timber either

- made of edge bonded timber layers, or
- made of timber layers, which have a thickness of up to 45 mm (including), which are not edge bonded and comprise laminations having a ratio of lamination width to lamination thickness greater than or equal to four,

the characteristic rolling shear strength $f_{v,9090,k}$ may be taken as $f_{v,9090,k} = 1,1 \text{ N/mm}^2$ without testing. Grooves in laminations shall be regarded as free (non bonded) edges.

If a ratio of lamination width to lamination thickness is not limited in a non edge bonded timber layer having a thickness of up to 45 mm (including) the characteristic rolling shear strength $f_{v,9090,k}$ may be taken as $f_{v,9090,k} = 0,7 \text{ N/mm}^2$, without testing.

If the characteristic compression strength perpendicular to the grain of a cross laminated timber only made from timber layers is not determined by tests, it may be taken as $f_{c,90,xlam,k} = 3 \text{ N/mm}^2$.

The characteristic density of the cross laminated timber may be taken as $\rho_{xlam,k} = 1,1 \rho_{lay,k}$ where $\rho_{lay,k}$ is the characteristic density of the lowest declared timber grade of a timber layer within the cross laminated timber. The mean density of the cross laminated timber shall be taken as $\rho_{xlam,mean} = \rho_{lay,mean}$ where $\rho_{lay,mean}$ is the mean density of the lowest declared timber grade of a timber layer within the cross laminated timber.

5.2.3.3 Determination from tests with cross laminated timber

If the strength and stiffness properties of the cross laminated timber are determined from tests, these tests shall be done and evaluated according to Annex F. The strength and stiffness properties of the cross laminated timber shall be expressed as:

- geometrical data (cross sectional sizes, layer thicknesses and orientations, grooves (if relevant), presence of edge bonds (if relevant), and ratio of lamination width to lamination thickness according to 5.2.2);
- strength, stiffness and density properties of timber and wood based panel layers, if relevant, calculated from test results and;
- bending strength(s) of the large finger joints according to 5.2.4, if relevant.

5.2.4 Strength and stiffness properties of cross laminated timber with large finger joints

For cross laminated timber with large finger joints the characteristic bending strength(s) $f_{m,lfg,k}$ of the large finger joints shall also be tested and declared in accordance with F.3.5 and F.4.5 in the directions (flat- or edgewise) relevant for the intended use.

5.2.5 Bonding strength

5.2.5.1 General

Bonds may be considered durable and reliable satisfied if the respective minimum production requirements given in Annex I and the requirements given in 5.2.2.3, 5.2.2.4 and 5.2.2.7 are fulfilled.

Bonding strength is defined by

- bonding strength of finger joints in laminations according to 5.2.5.2 tested for bending or tension strength of finger joints according to 5.1.2 and declared as bending strength of timber;
- bonding strength of glue lines between layers, tested and declared according to 5.2.5.4;
- bonding strength of edge bonds between laminations, tested and declared according to 5.2.5.3, if relevant; and
- bonding strength of large finger joints, tested according to 5.2.5.5, and declared as bending strength(s) of large finger joints according to 5.2.4, if relevant.

5.2.5.2 Bonding strength of finger joints in laminations

Finger joints in laminations may be considered durable and reliable if the respective minimum production requirements given in I.4 are fulfilled.

Bonding strength of finger joints in laminations shall be verified by bending or tension strength tests according to 5.1.2.

5.2.5.3 Bonding strength of bonds in edge bonded timber layers (shear test)

The bonding strength of edge bonds between laminations shall be verified by shear tests according to Annex D, if these glue lines are declared as load bearing glue lines, and declared as “Pass Shear”.

The bonding strength of edge bonds is proved to be sufficient, if the characteristic shear strength of the edge bonds $f_{v,k}$ derived from tests is $f_{v,k} \geq 3,5 \text{ N/mm}^2$. If a single tested glue line has a shear strength of $f_v < 2 \text{ N/mm}^2$ the wood failure percentage in this glue line shall be 100 %.

5.2.5.4 Bonding strength of glue lines between layers

5.2.5.4.1 General

Bonds between laminations may be considered durable and reliable if the respective minimum production requirements given in I.5 are fulfilled.

The bonding strength of glue lines between layers shall be verified either by delamination test according to 5.2.5.4.2 or by shear test according to 5.2.5.4.3. The shear test according to 5.2.5.4.3 is the reference test method. No correlation between delamination test and shear test results is given.

5.2.5.4.2 Bonding strength of glue lines between layers (delamination test)

The glue line integrity of glue lines between layers shall be verified by delamination test according to Annex C and declared as test method “Pass Delam”.

The bonding strength of glue lines between layers is proved to be sufficient, if the maximum delamination length does not exceed 40 % of the total length of a single glue line and the total delamination length does not exceed 10 % of the sum of all glue lines. Where the maximum delamination length or the total delamination length exceeds the limits given above or if the delamination lengths cannot be estimated due to the inadequate surface quality of the end grain

surfaces each glue line shall be split. The minimum wood failure percentage of each split glued area shall be not less than 50 %, the minimum wood failure percentage of the sum of all split glued areas shall be not less than 70 %.

5.2.5.4.3 Bonding strength of glue lines between layers (shear test)

The bonding strength of glue lines between layers shall be verified by shear tests according to Annex D and declared as test method “Pass Shear”,

The bonding strength of glue lines between crosswise bonded layers is proved to be sufficient, if the characteristic shear strength $f_{v,k}$ derived from tests is $f_{v,k} \geq 1,25 \text{ N/mm}^2$ and the shear strength f_v of each glue line is at least 1 N/mm^2 .

The bonding strength of glue lines between parallel bonded layers is proved to be sufficient, if the characteristic shear strength $f_{v,k}$ derived from tests is $f_{v,k} \geq 3,5 \text{ N/mm}^2$. If a tested glue line has a shear strength of $f_v < 2 \text{ N/mm}^2$ the wood failure percentage in this glue line shall be 100 %.

5.2.5.5 Bonding strength of large finger joints

Large finger joints may be considered durable and reliable if the respective minimum production requirements given in I.6 are fulfilled.

Bonding strength of large finger joints shall be verified by bending strength tests according to 5.2.4 and declared as bending strength of large finger joints according to 5.2.4.

5.2.6 Resistance to fire

When required, resistance to fire of cross laminated timber shall be declared as the following proxy parameters:

- geometrical data (e.g. cross sectional sizes and layup), in accordance with 5.2.2 and;
- charring rate (of layers), assessed on the basis of the species used, as given in 5.1.5; and the characteristic density expressed as strength class of timber layer, in accordance with 5.1.3 or technical class according to 5.1.4 or as single value.

NOTE Resistance to fire of cross laminated timber can be calculated later under a fire engineering design for specific end-use situation taking into account additional parameters, e.g. charring rates, given in the respective fire design code.

5.2.7 Reaction to fire

5.2.7.1 General

When required, the class of reaction to fire performance (including the additional classification on smoke production and flaming droplets/particles, if any) of cross laminated timber, both preservative treated against biological attack or not, shall be either:

- declared as the reaction to fire class of the timber layers according to 5.2.7.2 or;
- tested and declared according to 5.2.7.3.

5.2.7.2 Declaration as reaction to fire class of layers

The reaction to fire performance of cross laminated timber may be taken as the reaction to fire performance(s) of its layers. The reaction to fire performance of timber layers shall be determined according to EN 14081-1 and the reaction to fire performance of wood based panel layers according to EN 13986.

Either the reaction to fire classes of all layers or the class of the layer having the lowest reaction to fire class shall be declared.

5.2.7.3 Declaration on the basis of tests

5.2.7.3.1 General

The cross laminated timber shall be tested and classified according to EN 13501-1 and the standards referred therein for the corresponding reaction to fire classes.

Tests may be done without conditioning according to EN 13238 with specimens having a moisture content of $u \leq 15$ %. The moisture content shall be reported.

Unless the reaction to fire performance is determined from tests, the influence of a preservative treatment against biological attack on the performance of reaction to fire shall be taken into account as laid down in EN 15228:2009, 4.4.

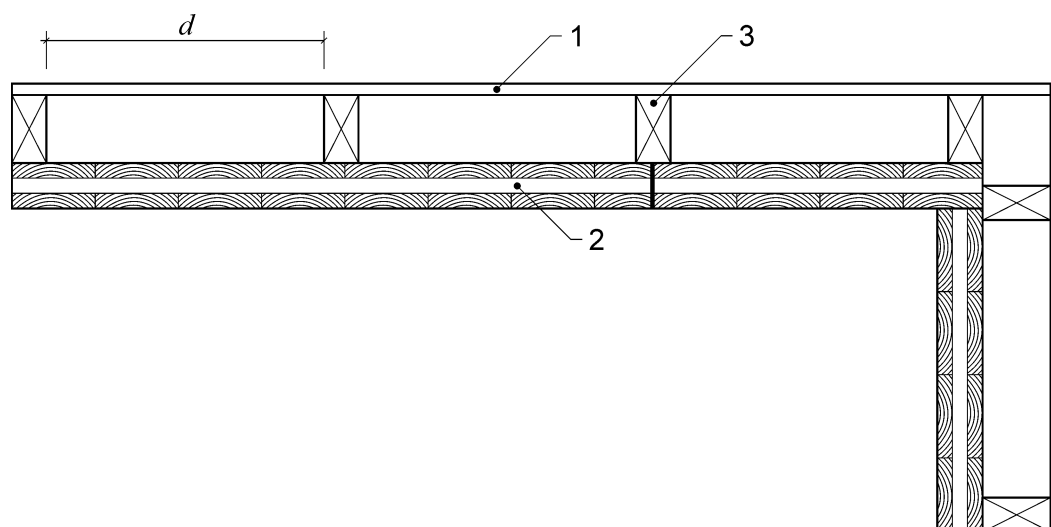
Reaction to fire class of cross laminated timber with large finger joints shall be considered as the reaction to fire class of the cross laminated timber components.

5.2.7.3.2 Mounting and fixing conditions

For tests according to EN 13823 (SBI test) specimens of cross laminated timber shall be mounted and fixed as follows:

- the whole area of both wings in the SBI apparatus shall be covered with pieces of the cross laminated timber concerned, mounted edge to edge (butt jointed), without jointing or bonding and orientated horizontally or vertically;
- supported by battens of the cross laminated timber concerned of a size minimum (40 × 80) mm, fixed to the test backing boards at 400 mm to 600 mm centres horizontally or vertically (perpendicular to the orientation of the cross laminated timber pieces), so that the resulting spacing between backing board and cross laminated timber is 80 mm;
- see also Figure 8.

Test results are valid for cross laminated timber having at least the densities and the minimum overall thickness of the specimens tested.



Key

$400 \text{ mm} \leq d \leq 600 \text{ mm}$

- 1 backing board
- 2 cross laminated timber
- 3 batten (cross section of 40 mm x 80 mm)

Figure 8 — Top view of fixing system for reaction to fire test according to EN 13823

5.2.8 Dimensional stability

The sizes of timber change by swelling and shrinkage due to changes of moisture content (for moisture contents below fibre saturation point which can be taken as 25 % for coniferous species). Changes in sizes due to changes of moisture content are determined according to 5.2.2.6. The moisture deformation factor depends on the species.

Dimensional stability shall be declared either as moisture deformation factor according to 5.2.2.6 or as species.

5.2.9 Release of dangerous substances

5.2.9.1 Formaldehyde emission

If required, the release of formaldehyde shall be tested according to Annex A and declared as either Class E1 or class E2 given in that Annex.

NOTE Cross laminated timber of class E2 may be banned in some member states.

5.2.9.2 Release/content of other dangerous substances

National regulations on dangerous substances may require verification and declaration on release and sometimes on content of other dangerous substances in addition to those dealt with in other clauses when construction materials covered by this Standard are placed on those markets.

In the absence of European harmonized test methods, verification and declaration on release/content should be done taking into account national provisions in the place of use.

NOTE An informative database covering European and national requirements on dangerous substances is available at the Construction website on EUROPA accessed through: http://ec.europa.eu/growth/tools-databases/cp-ds/index_en.htm.

5.2.10 Durability

5.2.10.1 Durability of bonding strength

Durability of bonding strength shall be expressed as:

- species according to 5.1.5;
- adhesive type and adhesive family according to 5.1.6;
- and declaration of minimum pressing time according to 5.1.6.2 or 5.1.6.3 or 5.1.6.4.1, if required at the place of intended use.

5.2.10.2 Durability against biological attack

5.2.10.2.1 General

If the cross laminated timber is solely built up of timber layers the durability against biological attack shall be declared as the durability of the timber. If the cross section is built up of different species or of treated and untreated layers only the natural durability or the preservative treatment of the layer with the lowest durability needs to be declared.

If the cross laminated timber comprises wood-based panel layers the technical class of these wood-based panels, where applicable, shall be declared additionally. If the cross section comprises different types of wood-based panels only the technical class of the wood-based panel with the lowest durability needs to be declared.

5.2.10.2.2 Timber layers without preservative treatment

The natural durability of cross laminated timber shall be taken as the natural durability according to EN 350-2 of the timber from which they are made. For species not listed in EN 350-2, the natural durability shall be verified according to EN 350-1.

5.2.10.2.3 Timber layers with preservative treatment

Only treatments according to EN 15228:2009, 4.5, which do not affect the strength, stiffness and density properties shall be used.

If either the preservative treated timber is used for the layers of the cross laminated timber, or the cross laminated timber itself is preservative treated, the information given in EN 15228:2009, Clause 6, shall be declared.

Requirements according to EN 15228 apply to the cross laminated timber as supplied, e.g. planing needs to be taken into account regarding retention and penetration depth.

NOTE The use of timber preservatives may be restricted by requirements valid in the place of use.

5.2.10.2.4 Wood-based panels

The technical class of wood-based panels according to EN 13986 shall be declared.

The durability of LVL according to EN 14374 shall be declared as the natural durability according to EN 350-2 of the timber from which it is made of. For species not listed in EN 350-2, the natural durability shall be verified according to EN 350-1.