Deutsches Institut für Bautechnik

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Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment ETA-11/0210 of 5 July 2016

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Merkle X-Lam
Product family to which the construction product belongs	Solid wood slab element to be used as a structural element in buildings
Manufacturer	Merkle Holz GmbH Straßer Weg 24 89278 Nersingen-Oberfahlheim DEUTSCHLAND
Manufacturing plant	Merkle Holz GmbH Straßer Weg 24 89278 Nersingen-Oberfahlheim DEUTSCHLAND
This European Technical Assessment contains	19 pages including 6 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	European Assessment Document (EAD) 130005-00-0304

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Specific Part

1 Technical description of the product

Merkle X-Lam cross laminated timber elements are made of softwood boards which are bonded together to form cross laminated timber elements consisting of 3 to 9 layers. Adjacent layers of the softwood boards are bonded perpendicular (angle of 90°) to each other. In elements with at least five layers, up to two adjacent layers each may be oriented with parallel grain direction.

The lay-up of the cross laminated timber shall be symmetrical about its centre plane. The elements are plane.

The principle structure of the cross laminated timber is shown in Annex 1, Figure 1 and Figure 2.

Wood species are spruce, fir, pine, Douglas fir and larch.

Manufacturing

The cross laminated timber elements are manufactured in accordance with the provisions of this European Technical Assessment using the automated manufacturing process in accordance with in the technical documentation.

The layers shall be glued together to the required thickness of the cross laminated timber.

Specifications of the used boards are given in Annex 2. Boards are visually or machine strength graded. Only technically dried wood shall be used.

The boards may be connected by finger joints in longitudinal direction according to EN 14080[1]. There shall be no butt joints.

The solid wood slab elements correspond to the specifications given in Annexes 1 to 3 of this European Technical Assessment. The material characteristics, dimensions and tolerances of the solid wood slab elements not indicated in these Annexes are given in the technical documentation of the European Technical Assessment.

2 Specification of the intended use in accordance with the applicable European Assessment Document

The solid wood slab element is intended to be used as a structural or non-structural element in buildings and timber structures. The solid wood slab shall be subjected to static and quasi-static actions only.

The solid wood slab is intended to be used in service classes 1 and 2 according to EN 1995-1-1.

Members which are directly exposed to the weather shall be provided with an effective protection for the solid wood slab element in service.

The performances given in Section 3 are only valid if the solid wood slab elements are used in compliance with the specifications and conditions given in Annex 1 to 6.

The verifications and assessment methods on which this European Technical Assessment is based lead to the assumption of a working life of the solid wood slab element of at least 50 years. The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

[1] EN 14080:2013 Timber structures - Glued laminated timber and glued solid timber - Requirements

Design

The European Technical Assessment only applies to the manufacture and use of solid wood slab elements. Verification of stability of the building while using the solid wood slab elements is not subject of the European Technical Assessment.

The following conditions shall be observed:

- Design of the solid wood slab elements is carried out under the responsibility of an engineer experienced in such products.
- Design of the works shall account for the protection of the solid wood slab elements.
- The solid wood slab elements are installed correctly.

Design of the solid wood slab element can be performed according to EN 1995-1-1, taking into account of Annexes 2 to 6 of the European Technical Assessment. Standards and regulations valid in the place of use shall be considered.

Packaging, transport, storage, maintenance and repair

The solid wood slab elements shall be protected during transport and storage against any damage and detrimental moisture effects. The manufacturer's instructions for packaging, transport and storage shall be observed.

The assessment of the fitness for use is based on the assumption that maintenance is not required during the assumed intended working life. In case of a severe damage of a solid wood slab element immediate actions regarding the mechanical resistance and stability of the works shall be initiated. Should this situation arise replacement of the elements can be necessary.

Installation

The manufacturer shall prepare assembling instructions in which the product-specific characteristics and important measures to be taken into consideration for assembling are described. The assembling instructions shall be available at every construction site.

The assembling of the solid wood slab elements according to this European Technical Assessment shall be carried out by appropriately qualified personnel.

Solid wood slab elements shall be protected against detrimental change of moisture. The safety-at-work and health protection regulations have to be observed.

3 Performance of the product and references to the methods used for its assessment

3.1 Mechanical resistance and stability [1)] (BWR 1)

Essential characteristic	Performance
Bending [2)]	Annex 3
Tension and compression [2)]	Annex 3
Shear [2)]	Annex 3
Embedment strength	Annex 3
Creep and duration of the load	Annex 3
Dimensional stability	Annex 3
In-service environment	Annex 3
Bond integrity	Annex 3

[1)] This characteristic also relates to BWR 4.

[2)] Load bearing capacity and stiffness regarding mechanical actions perpendicular to and in plane of the solid wood slab element.

For gluing the cross laminated timber an adhesive type 1 according to EN 301[2] is to be used.

For the finger joints of the individual boards a PU-adhesive type I fulfilling the requirements of EN 15425[3] and EN 14080[4], Annex C, is to be used.

Details on the adhesives are deposited with Deutsches Institut für Bautechnik.

3.2 Safety in case of fire (BWR 2)

Essential characteristic	Performance
Reaction to fire	Annex 3
Resistance to fire	Annex 3

3.3 Hygiene, health and the environment (BWR 3)

Essential characteristic	Performance
Content and release of dangerous substances	The product does not contain dangerous substances > 0.1 wt. % according to EOTA TR 034 (version October 2015).
	Emission analysis (extraction from test report after 3 or 28 days): Test method: prEN 16516 Chamber conditions: DIN ISO 16000-9 Chamber size: 1.000 m^3 Loading factor: 0.4 m^2/m^3 After 3 days: Sum VOC and SVOC with NIK1): 0.089 mg/m^3 Sum of carcinogens (EU-cat. 1A and 1B): < 0.001 mg/m^3 After 28 days: Sum VOC and SVOC with NIK1): 0.07 mg/m^3 Sum SVOC except NIK1): < 0.005 mg/m^3 Sum VOC except NIK1): < 0.005 mg/m^3 R-value (NIK-list 2015): 0.17 Sum of carcinogens (EU-cat. 1A and 1B): < 0.001 mg/m^3 Regarding the emission of dangerous substances into indoor air the product meets the requirements of Germany. The chemical composition of the product and the test report for the emission analysis are deposited at the Technical Assessment Body (DIBt).
Formaldehyde emission	The manufacturer has submitted a written declaration to the Technical Assessment Body (DIBt) that the solid wood slab elements according to this European Technical Assessment can be assigned to formaldehyde class E1.

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

[3] EN 15425:2008 — Adhesives - One component polyurethane for load bearing timber structures - Classification and performance requirements

[4] EN 14080:2013 — Timber structures - Glued laminated timber and glued solid timber - Requirements

Essential characteristic	**Performance**
Wood preservatives or flame retardants	Wood preservatives and flame retardants are not subject of the ETA.
Use scenarios regarding BWR 3 in accordance with EOTA TR 034: IA 1, IA 2, IA 3	
Water vapour permeability Water vapour transmission	no performance assessed

[1)] The sum VOC (C_6-C_{16}) and the sum of SVOC (C_{16}-C_{22}) considers only substances ≥ 5 µg/m³.

3.4 Safety and accessibility in use (BWR 4)

Essential characteristic	**Performance**
Impact resistance	Annex 3

3.5 Protection against noise (BWR 5)

Essential characteristic	**Performance**
Airborne sound insulation	no performance assessed
Impact sound insulation	no performance assessed
Sound absorption	no performance assessed

3.6 Energy economy and heat retention (BWR 6)

Essential characteristic	**Performance**
Thermal conductivity	no performance assessed
Air permeability	no performance assessed
Thermal inertia	no performance assessed

3.7 Sustainable use of natural resources (BWR 7)

The performance of this product in terms of sustainable use of natural resources has not been investigated.

4 Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with EAD No. 130005-00-0304 the applicable European legal act is: 1997/176/EC amended by 2001/596/EC

The system to be applied is: 1

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited with Deutsches Institut für Bautechnik.

Issued in Berlin on 5 July 2016 by Deutsches Institut für Bautechnik

Uwe Bender
Head of Department

beglaubigt:
Deniz

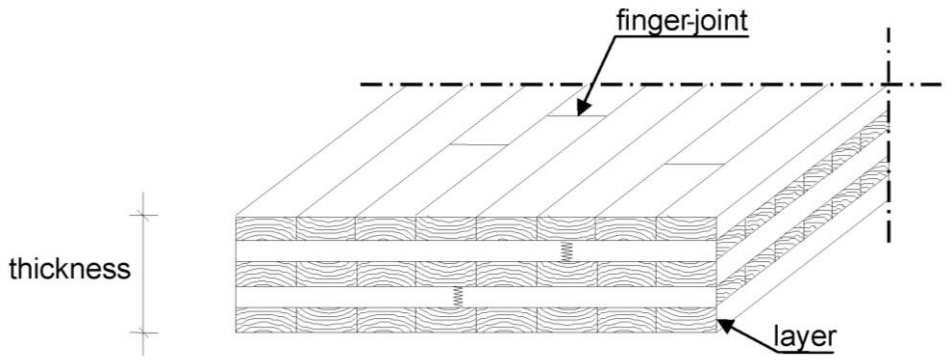

Figure 1: Principle structure of the cross laminated timber element (five layers)

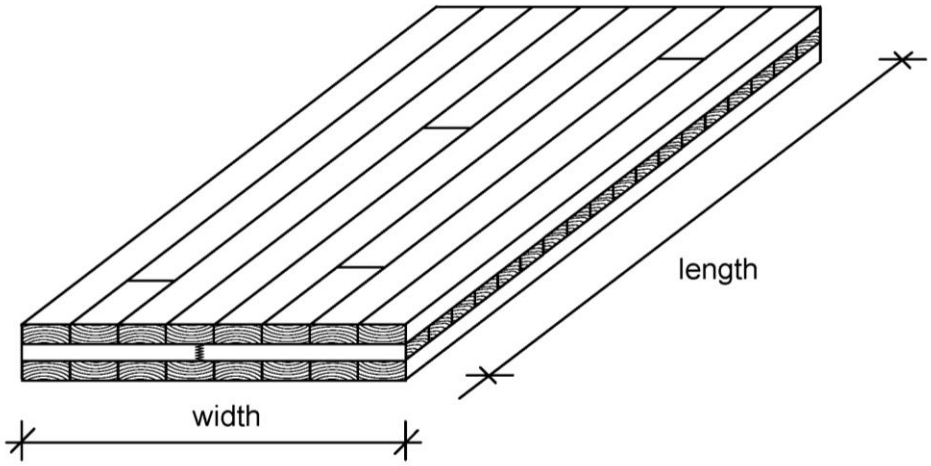

Figure 2: Cross laminated timber element (three layers)

Merkle X-Lam	Annex 1
Structure of cross laminated timber	

Table 1: Dimensions and specifications of the elements

Characteristic	Specification
Cross laminated timber element	
Thickness	60 to 300 mm
Tolerance in thickness	± 1 mm
Width	≤ 3.00 m
Tolerance in width	± 3 mm
Length	≤ 18.00 m
Tolerance in length	± 3 mm
Number of layers	$3 \leq n \leq 9$
Number of consecutive layers having the same grain direction	≤ 2 for $n \geq 5$
Maximum width of gaps between adjacent boards in longitudinal layers in cross layers	 3 mm 6 mm
Boards	
Material	spruce, fir, pine, Douglas fir and larch
Strength class according to EN 338[1] resp EN 14081-1[2]	≥ C16 *)
Surface of the boards	planed
Thickness in longitudinal layers in cross layers	20 to 80 mm 20 to 40 mm
Width	80 to 240 mm
Ratio width to thickness of the cross-layers	≥ 4:1
Moisture of wood according to EN 13183-2[3]	10±2; 11±2, 12±2 Within one cross laminated timber element only one of the specified moisture ranges shall be applied.
Finger joints	EN 385
*) In each layer 10 % of a lower strength class may be used.	

1 EN 338:2009 Timber structures - Strength classes
2 EN 14081-1:2005 Timber structures - Strength graded structural timber with rectangular cross section - Part 1: General requirements
3 EN 13183-2:2002 Moisture content of a piece of sawn timber - Part 2: Estimation by electrical resistance method

Merkle X-Lam

Dimensions and specifications of the elements of the cross laminated timber

Annex 2

Table 2: Essential requirements of the cross laminated timber

ER	Requirement	Verification method	Class / Use category / Value
1	**Mechanical resistance and stability**		
	For the calculation of the characteristic strength and stiffness values of softwood according to EN 338[1] shall be used taking into consideration the definitions in Annex 2. In addition the following values apply:		
	Panel shear strength	Shear strength for the calculation with the gross cross section (5% fractile)	$f_{v,k}$ as given in Table 3
	Bending strength	Rolling shear strength (5% fractile)	$f_{R,k}$ as given in Figure 3
		Rolling shear modulus (mean value)	$G_{R,mean}$ 50 N/mm²
	For references regarding the calculation see Annexes 4 to 6. National regulations might have to be followed.		
	Use of fasteners	according to EN 1995-1-1, for further details see Annex 5	
	Creep and duration of load	according to EN 1995-1-1	
	Dimensional stability	Moisture content during use shall not change to such extent that adverse deformations can occur.	
	In-service environment	EN 1995-1-1	1 and 2
	Bond integrity	EAD 130005-00-0304	Passed
2	**Behaviour in case of fire**		
	Reaction to fire		
	Solid wood panels except for floorings	Commission Decision 2005/610/EC	Euroclass D-s2, d0
	Floorings		Euroclass D_{fl}-s1
	Resistance to fire		
	Charring rate only applies for tightly butted boards	EN 1995-1-2[4]	β_0 = 0.65 mm/min β_n = 0.7 mm/min
3	**Hygiene, health and the environment**		
	Water vapour resistance factor μ	no performance assessed	
	Content of dangerous substances	EAD 130005-00-0304	See clause 3
4	**Safety in use**		
	Impact resistance	Soft body resistance is assumed to be fulfilled for walls with a minimum of 3 layers and minimum thickness of 60 mm.	
5	**Protection against noise**		
	Airbourne sound insul.	no performance assessed	
	Impact sound insulation	no performance assessed	
	Sound absorption	no performance assessed	
6	**Energy economy and heat retention**		
	Thermal conductivity λ	no performance assessed	
	Air tightness	no performance assessed	
	Termal inertia c_p	no performance assessed	

[4] EN 1995-1-2:2004 + AC:2009 Eurocode 5: Design of timber structures – Part 1-2: General –Structural fire design

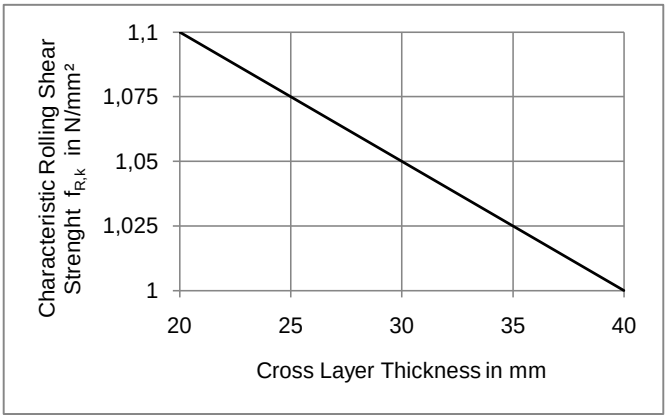

Figure 3: Rolling Shear Strength $f_{R,k}$

Merkle X-Lam	Annex 3
Essential requirements of the cross laminated timber	

Table 3: Characteristic shear strength $f_{v,k}$ calculated with the gross cross section (for mechanical actions in plane of the cross laminated timber)

Element thickness in mm	Number of layers	Thickness of individual layers in mm (written in **bold** characters for longitudinal layers)									$f_{v,k}$ in N/mm²
60	3	**20**	20	**20**							2.1
80	3	**30**	20	**30**							1.8
85	3	**30**	25	**30**							2.0
90	3	**30**	30	**30**							2.2
100	3	**30**	40	**30**							2.1
100	3	**40**	20	**40**							1.6
105	3	**40**	25	**40**							1.8
110	3	**40**	30	**40**							1.9
120	3	**40**	40	**40**							2.2
120	3	**50**	20	**50**							1.3
125	3	**50**	25	**50**							1.6
130	3	**50**	30	**50**							1.7
140	3	**50**	40	**50**							2.0
140	3	**60**	20	**60**							1.1
145	3	**60**	25	**60**							1.4
150	3	**60**	30	**60**							1.6
160	3	**70**	20	**70**							1.0
165	3	**70**	25	**70**							1.2
170	3	**70**	30	**70**							1.4
180	3	**70**	40	**70**							1.7
180	3	**80**	20	**80**							0.9
185	3	**80**	25	**80**							1.1
190	3	**80**	30	**80**							1.3
200	3	**80**	40	**80**							1.6
130	5	**30**	20	**30**	20	**30**					2.2
140	5	**30**	25	**30**	25	**30**					2.4
150	5	**30**	30	**30**	30	**30**					2.7
160	5	**40**	20	**40**	20	**40**					2.0
170	5	**40**	25	**40**	25	**40**					2.2
180	5	**40**	30	**40**	30	**40**					2.3
190	5	**40**	35	**40**	35	**40**					2.5
200	5	**40**	40	**40**	40	**40**					2.7
220	7	**40**	20	**40**	20	**40**	20	**40**			2.2
235	7	**40**	25	**40**	25	**40**	25	**40**			2.4
240	7	**40**	**40**	20	**40**	20	**40**	**40**			1.3
250	7	**40**	30	**40**	30	**40**	30	**40**			2.5
280	7	**40**	40	**40**	40	**40**	40	**40**			2.9
280	9	**40**	20	**40**	20	**40**	20	**40**	20	**40**	2.3
300	9	**40**	25	**40**	25	**40**	25	**40**	25	**40**	2.5
300	9	**40**	**40**	20	**40**	20	**40**	20	**40**	**40**	1.7

Merkle X-Lam

Essential requirements of the cross laminated timber

Annex 3

Deutsches Institut für Bautechnik DIBt

1 Mechanical actions perpendicular to the element plane

Stress distribution within the elements shall be calculated taking into account the shear deformation of the cross layers.

For simply supported cross laminated timber elements with up to 5 layers the stress distribution may be calculated according to EN 1995-1-1, Annex B, as mechanically jointed beam where the value s_i/K_i is substituted by $\overline{h}_i/(G_R \cdot b)$

with $\overline{h}_i$ = thickness of the cross layer

G_R = 50 N/mm² shear modulus of the cross layer

b = width of the cross layer.

(Design according to the theory of flexible bonded beams see Annex 6)

For cross laminated timber with more than 5 layers it is necessary to use numerical solutions offered by computer programs taking into account the shear deformation of the cross layers.

For the design of cross laminated timber the characteristic strength and stiffness values shall be taken from Annex 3.

For the bending design only the stresses at the edges of the boards are decisive.

For the verification of the bending strength the design bending strength value of a layer of boards may be multiplied by a system strength factor k_ℓ:

$$k_\ell = \min \begin{cases} 1 + 0.025 \cdot n \\ 1.2 \end{cases}$$

with n = number of boards within a layer

Tension loads perpendicular to the plane of the element shall be avoided.

2 Mechanical actions in plane of the element

Stress distribution within the elements shall be calculated by taking into account only the boards which are oriented in the direction of the actions.

Shear stresses may be calculated with the total thickness of the cross laminated timber.

For the design of cross laminated timbers the characteristic strength and stiffness values shall be taken from Annex 3.

For the verification of the bending strength the design bending strength value of a layer of boards may be multiplied by a system strength factor k_ℓ:

$$k_\ell = \min \begin{cases} 1 + 0.025 \cdot n \\ 1.2 \end{cases}$$

with n = number of longitudinal layers

Merkle X-Lam	Annex 4
Design of the cross laminated timber	

Deutsches Institut für Bautechnik DIBt

1 General

The design rules given in this section amend the design rules for connections given in EN 1995-1-1.

Plane sides are the surfaces of the element parallel to the plane of the element, narrow sides are the surfaces perpendicular to the plane sides of the element.

1.1 Perpendicular to the axis loaded dowel type fasteners

1.1.1 Joints in the plane side of cross laminated timber

Embedding strength:

For nails, self-tapping screws, dowels and bolts in the plane side of cross laminated timber the embedding strength of solid timber may be used, depending on the characteristic density of the laminations of the cross laminated timber and on the angle between force and grain direction of the outer layer.

The following conditions shall be fulfilled:

- Diameter of nails $d \geq 4$ mm
- Outer thread diameter of self-tapping screws $d \geq 6$ mm

Effective number of fasteners:

The effective number of fasteners n_{ef} for outer layers with a thickness ≤ 40 mm shall be taken from equation (1).

$n_{ef} = n$ with n number of fasters within one row (1)

For outer layers with a thickness > 40 mm the effective number of fasteners n_{ef} according to EC 5 (8.3.1.1) shall be used.

Minimum spacings, edge and end distances:

Minimum spacings, edge and end distances and angle α between the force and the grain direction of the outer layers as defined in Figure 4 are given in Table 4.

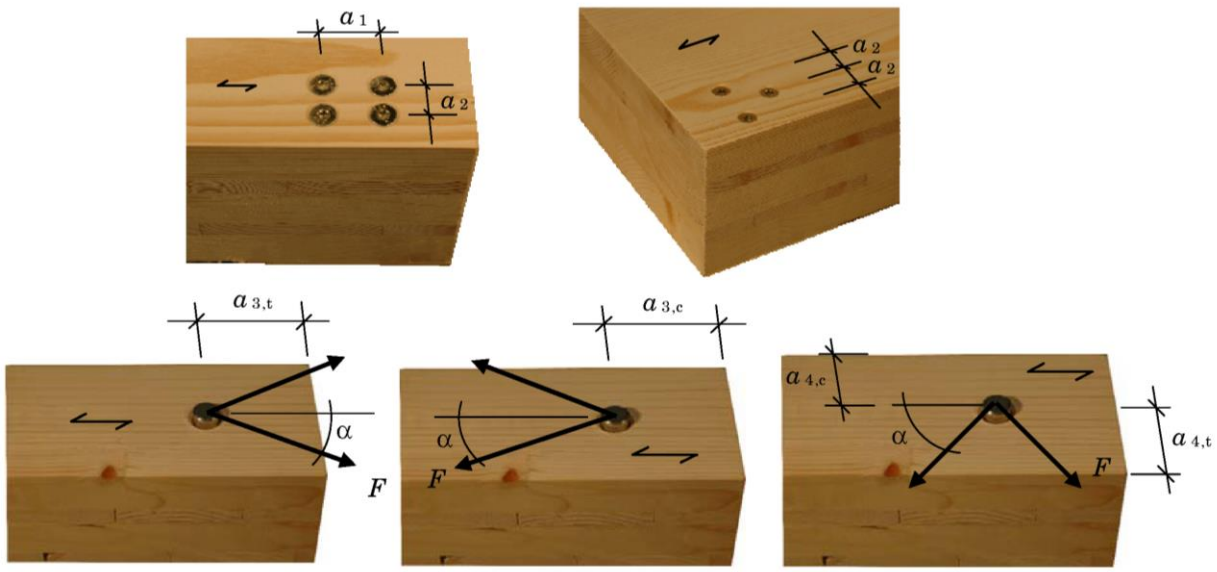

Figure 4: Definitions of minimum spacings, edge and end distances for laterally loaded dowel-type fasteners in the plane side of cross laminated timber

Merkle X-Lam	Annex 5
Design of connectors	

Table 4: Definitions of minimum spacings, edge and end distances in the plane side of cross laminated timber elements

	a_1	$a_{3,t}$	$a_{3,c}$	a_2	$a_{4,t}$	$a_{4,c}$
Nails	(3+3 cos α)d	(7+3 cos α)d	6 d	3 d	(3+4 sin α) d	3 d
Self-tapping screws	4 d	6 d	6 d	2,5 d	6 d	2,5 d
Dowels	(3+2 cos α) d	5 d	$\max \begin{cases} 4d \cdot \sin\alpha \\ 3d \end{cases}$	3 d	3 d	3 d
Bolts	$\max \begin{cases} (3+2\cos\alpha)d \\ 4\,d \end{cases}$	5 d	4 d	4 d	3 d	3 d

1.1.2 Joints in the narrow side of cross laminated timber

Embedding strength:

The characteristic embedding strength for self-tapping screws with a diameter d ≥ 8 mm in the narrow sides of cross laminated timber may be calculated according to equation (2).

$$f_{h,k} = 20\ d^{-0.5} \quad \text{in N/mm}^2 \qquad (2)$$

where

d = Nominal diameter of the self-tapping screws in mm

For actions perpendicular to the plane side of the cross laminated timber the possibility of splitting caused by the tension force component perpendicular to the grain, shall be taken into account. Connections with ratios $h_e/h < 0.7$ should be reinforced with fully threaded screws (see example in Figure 5).

where

h_e = Loaded edge distance to the centre of the most distant fastener

h = Thickness of the cross laminated timber

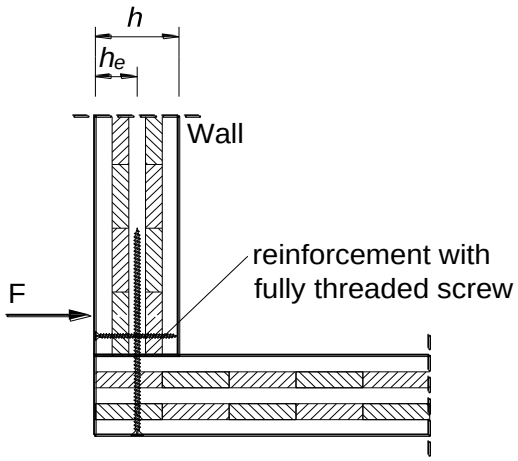

Figure 5: Reinforcement of a cross laminated timber wall with fully threaded screws

Effective number of fasteners:

The effective number of fasteners n_{ef} according to EC 5 (8.3.1.1) shall be used.

Minimum spacings, edge and end distances:

Minimum spacings, edge and end distances as defined in Figure 6 and further requirements for connections with self-tapping screws in the narrow side of cross laminated timber are given in Table 5 and Table 6.

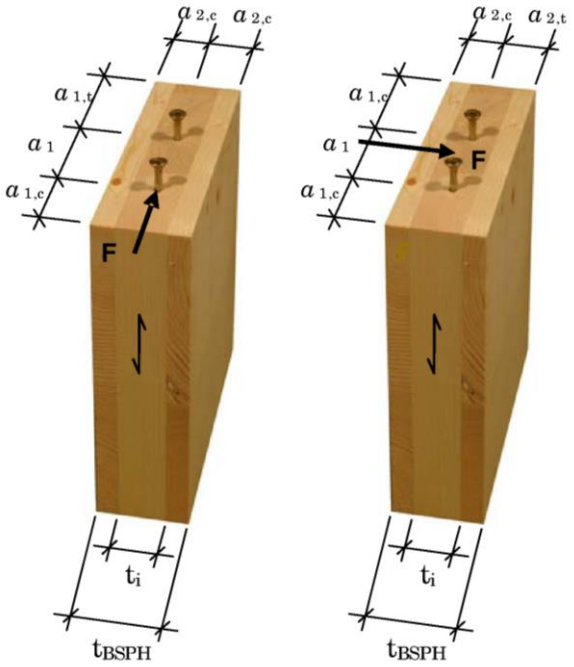

Figure 6: Definition of minimum spacings, edge and end distances for laterally loaded self-tapping screws in the narrow side of cross laminated timber

Table 5: Definition of minimum spacings, edge and end distances in the narrow side of cross laminated timber element

	a_1	$a_{3,t}$	$a_{3,c}$	a_2	$a_{4,t}$	$a_{4,c}$
Self-tapping screws	10 *d*	12 *d*	7 *d*	3 *d*	6 *d*	3 *d*

Table 6: Requirements for joints in the narrow side of cross laminated timber

	Minimum thickness of the relevant layer t_i in mm	Minimum thickness of the cross laminated timber t_{BSPH} in mm	Minimum penetration length of the fastener t_1 or t_2 in mm [a)]
Self-tapping screws	d > 8 mm: 3 · d d ≤ 8 mm: 2 · d	10 · d	10 · d
a) t_1 Minimum penetration length of the fastener in side members t_2 Minimum penetration length of the fastener in middle members			

Merkle X-Lam	Annex 5
Design of connectors	

1.2 Axially loaded dowel type fasteners

1.2.1 Threaded nails

The characteristic withdrawal capacity for threaded nails in the plane sides of cross laminated timber may be calculated according equation (3).

$$R_{ax,k} = 14 d^{0,6} \cdot \ell_{ef} \quad \text{in N} \qquad (3)$$

Where

d = Outer diameter of the threaded part

ℓ_{ef} = Penetration length of the threaded part

The following conditions should be fulfilled:

- At least two nails in a connection
- Diameter of the threaded part d ≥ 4 mm
- Penetration length of the threaded part $\ell_{ef} \geq 8\ d$
- Characteristic point side withdrawal parameter $f_{ax,k} \geq 50 \cdot 10^{-6} \cdot \rho_k^2$

with ρ_k = characteristic value of density (kg/m³)

1.2.2 Self tapping screws

Withdrawal capacity:

The characteristic withdrawal capacity for self-tapping screws in the plane sides or in the narrow sides of cross laminated timber may be calculated according equation (4).

$$R_{ax,k} = \sum_{i=1}^{n} f_{ax,i,k} \cdot \ell_{ef,i} \cdot d \quad \text{in N} \qquad (4)$$

where

d = Outer thread diameter of the threaded part, with d ≥ 6 mm for screws in the plane sides of cross laminated timber and d ≥ 8 mm for screws in the narrow sides of cross laminated timber

$f_{ax,i,k}$ = Characteristic withdrawal parameter of layer i depending on the characteristic density $\rho_{k,i}$ and the angle α_i between screw axis and grain direction of layer i

$\ell_{ef,i}$ = Penetration length of the threaded part in layer i

n = Number of penetrated layers

The following conditions should be fulfilled:

- Penetration length of the threaded part $\ell_{ef,i} \geq 4\ d$

Merkle X-Lam	Annex 5
Design of connectors	

For the design of axially loaded screws in cross laminated timber only threaded parts with an angle $\alpha \geq 30°$ between screw axis and grain direction may be taken into account.

Screws oriented parallel to the plane side of the cross laminated timber should be completely arranged within one layer. The outer diameter of the threaded part should not exceed the thickness of the layer the screw is arranged in.

The characteristic pull-through strength of the screw head for solid timber may be used, depending on the characteristic density of the layer at the head side of the screw.

1.3 Connections with split ring connectors and toothed-plate connectors

The characteristic value of the load-bearing capacity of split ring connectors and toothed-plate connectors in the plane sides of cross laminated timber may be calculated according to EN 1995-1-1.

For split ring connectors in the narrow sides of cross laminated timber the regulations for connections with split ring connectors in the end grain may be applied.

Toothed-plate connectors in the narrow sides of cross laminated timber shall not be taken into consideration as load-bearing.

Merkle X-Lam	Annex 5
Design of connectors	

Design according to the theory of flexible bonded beams

The calculation of elements with up to five layers can be performed using the theory of flexible bonded beams as described in EN 1995-1-1.

To consider deformations due to shear the factor s_i/K_i according to the standard is substituted by the factor $\bar{h}_i / (G_R \cdot b)$.

The effective moment of inertia is calculated by:

$$I_{ef} = \sum_{i=1}^{3} (I_i + \gamma_i \cdot A_i \cdot a_i^2) \qquad \text{with} \qquad A_i = b_i \cdot h_i; \qquad I_i = \frac{b_i \cdot h_i^3}{12}$$

$$\gamma_1 = \frac{1}{1 + \frac{\pi^2 \cdot E_0 \cdot A_1 \cdot \bar{h}_1}{G_R \cdot b \cdot l^2}}; \qquad \gamma_2 = 1; \qquad \gamma_3 = \frac{1}{1 + \frac{\pi^2 \cdot E_0 \cdot A_3 \cdot \bar{h}_2}{G_R \cdot b \cdot l^2}}$$

$$a_1 = \left(\frac{h_1}{2} + \bar{h}_1 + \frac{h_2}{2} \right) - a_2; \qquad a_3 = \left(\frac{h_2}{2} + \bar{h}_2 + \frac{h_3}{2} \right) + a_2$$

$$a_2 = \frac{\gamma_1 \cdot A_1 \cdot \left(\frac{h_1}{2} + \bar{h}_1 + \frac{h_2}{2} \right) - \gamma_3 \cdot A_3 \cdot \left(\frac{h_2}{2} + \bar{h}_2 + \frac{h_3}{2} \right)}{\sum_{i=1}^{3} (\gamma_i \cdot A_i)}$$

The verification of the bending performance is done by determination of the bending stress at the boundary of the boards. The bending stress in the middle of the boards may remain unconsidered.

$$\sigma_{m,r,i,d} = \pm \frac{M_d}{I_{ef}} \cdot \left(\gamma_i \cdot a_i + \frac{h_i}{2} \right) \le f_{m,d}$$

The verification of the shear performance is done by determination of the shear stress in the decisive plane:

$$\tau_{v,d} = \frac{V_d \cdot \gamma_i \cdot S_i}{I_{ef} \cdot b} \le f_{R,d}$$

Legend:

h_{tot} = thickness of the whole element [mm]

h_i = thickness of the layer i parallel to the direction of load transfer [mm]

$\bar{h}_i$ = thickness of the layer i perpendicular to the direction of load transfer [mm]

b = width of the element [mm]

n = number of layers

l = span width [mm]

I_{ef} = effective moment of inertia [Nmm²]

G_R = rolling shear modulus [N/mm²]

E_0 = modulus of elasticity parallel to the grain of the boards [N/mm²]