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Authorised and notified according to Article 29 of the Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011

MEMBER OF EOTA

European Technical Assessment ETA-18/1002 of 2019-01-07

I General Part

Technical Assessment Body issuing the ETA and designated according to Article 29 of the Regulation (EU) No 305/2011: ETA-Danmark A/S

Trade name of the construction product:	Merkle X-Lam with XL-Connect ®
Product family to which the above construction product belongs:	Solid wood slab elements to be used as structural elements in buildings
Manufacturer:	Merkle Holz GmbH Straßer Weg 24 D-89278 Nersingen Tel. +49 (07308) 9646 0 Fax +49 (07308) 9646 46 Internet www.merkleholz.de
Manufacturing plant:	Merkle Holz GmbH Straßer Weg 24 D-89278 Nersingen
This European Technical Assessment contains:	23 pages including 6 annexes which form an integral part of the document
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 “Solid wood slab element to be used as a structural element in buildings”
This version replaces:	

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II SPECIFIC PART OF THE EUROPEAN TECHNICAL ASSESSMENT

1 Technical description of product and intended use

Technical description of the product

Merkle X-Lam with XL-connect ® is a cross laminated timber element made of softwood consisting of an odd number of 3 layers up to 9 layers. The lay-up of the cross laminated timber shall be symmetrical to its centre plane. The elements are plane.

Individual layers consist of parallel oriented lamellae made of strength graded boards. In elements with at least five layers, two adjacent layers may be oriented with parallel grain direction.

The components and the system setup of the product are given in Annex 1, Figure 1 and Figure 2.

The application of chemical substances (wood preservatives and flame retardants) is not subject of the European technical assessment.

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

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 the technical documentation.

The layers shall be bonded 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. There shall be no butt joints.

The cross laminated timber elements correspond to the specifications given in Annexes 1 to 3 of this European technical assessment. The material characteristics, dimensions and tolerances of the cross laminated timber 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 cross laminated timber is intended to be used as a structural or non structural element in buildings and timber structures. The cross laminated timber shall be subjected to static and quasi static actions only. This includes seismic actions according to EN 1998-1.

The cross laminated timber 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 cross laminated timber element in service.

The performances given in Section 3 are only valid if the cross laminated timber 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 cross laminated timber 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.

Design

The European Technical Assessment only applies to the manufacture and use of cross laminated timber elements. Verification of stability of the building while using the cross laminated timber elements is not subject of the European Technical Assessment.

The following conditions shall be observed:

- Design of the cross laminated timber 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 cross laminated timber elements.
- The cross laminated timber elements are installed correctly.

Design of the cross laminated timber element can be performed according to EN 1995-1-1 and EN 1998-1, taking into account 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 cross laminated timber 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 is based on the assumption that maintenance is not required during the assumed intended working life. In case of a severe damage of a cross laminated timber 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 cross laminated timber elements according to this European technical assessment shall be carried out by appropriately qualified personnel.

Cross laminated timber 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*) (BWR1)

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 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 cross laminated timber element.	

For gluing the cross laminated timber an adhesive type 1 according to EN 301 is to be used. For the finger joints of the individual boards a PU-adhesive type 1 fulfilling the requirements of EN 15425 and EN 14080, Annex C is to be used. Specifications are deposited with ETA Danmark.

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 of dangerous substances	The manufacturer has submitted a written declaration to the Technical Assessment Body (ETA Danmark) that no dangerous substances > 0.1 wt. % are used in the product assessed by the present ETA. Only wood based panels which can be assigned to formaldehyde class E1 according to EN 13986 shall be used. The use of wood preservatives and flame retardants is excluded. The chemical composition of the adhesives for gluing the boards and the finger joints of the individual boards has to be in compliance with the chemical composition deposited at the Technical Assessment Body (ETA Danmark).
Release scenarios regarding BWR3	IA 1, IA2
Water vapour permeability - Water vapour transmission	Annex 3

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	Annex 3
Impact sound insulation	Annex 3
Sound absorption	Annex 3

3.6 Energy economy and heat retention (BWR 6)

Essential characteristic	Performance
Thermal conductivity	Annex 3
Air permeability	Annex 3
Thermal inertia	Annex 3

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 assessed.

4 Attestation and verification of constancy of performance (AVCP)

4.1 AVCP system

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 foreseen in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited at ETA-Danmark prior to CE marking.

Issued in Copenhagen on 2019-01-07 by

Thomas Bruun
Managing Director, ETA-Danmark

Annex 1
Construction of the wood slab elements "Merkle X-Lam" (example)

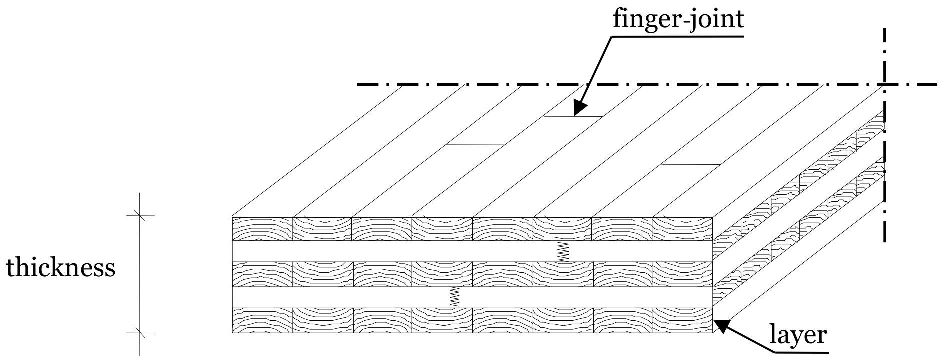


Figure 1: Principle structure of the cross laminated timber (five layers)

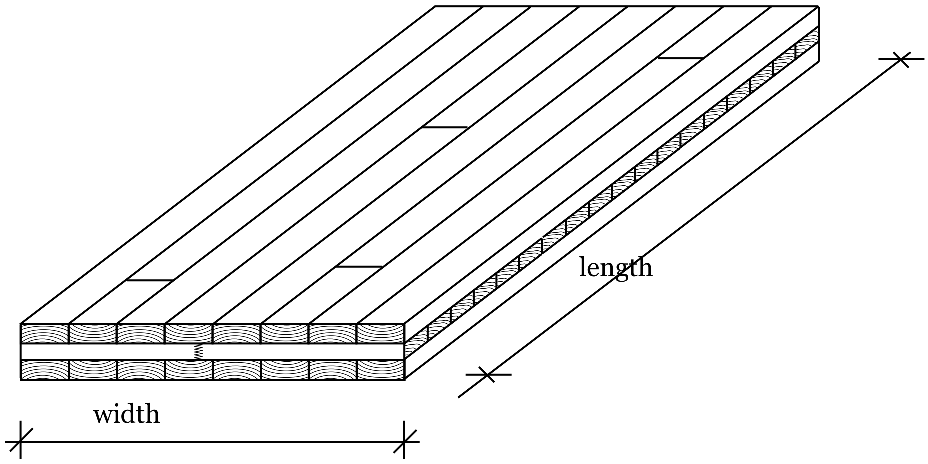


Figure 2: Cross laminated timber element (three layers)

Annex 2
Dimensions and specifications of the cross laminated timber

Table 1: Dimensions and specifications of the cross laminated timber

Characteristic	Dimensions and specifications
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	softwood
Strength class according to EN 14081-1 and EN 338 respectively	≥ C16 or ≥ T10
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 or EN 13183-3	At assembly, the moisture content of each board shall be between 6% and 15%. The moisture content of two boards to be jointed shall not differ more than 5 % in moisture content
Finger joints	EN 14080
The boards within a width of at least 90 % of the total width of the layer shall comply with the declared grade. The boards within a width of up to 10 % of the total width of the layer may deviate from the declared strengths parallel to the grain by not more than 35 %.	

Annex 3
Essential requirements of the cross laminated timber

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 the characteristic strength and stiffness values of softwood according to EN 338 shall be used taking into consideration the definitions in annex 2. In addition the following values apply:			
	Mechanical actions in plane of the cross laminated timber	Shear strength for the calculation with the gross cross section (5% - fractile)	$f_{v,k}$	as given in Table 3
	Mechanical actions perpendicular to the cross laminated timber	Rolling shear strength (5% - fractile)	$f_{R,k}$	as given in Figure 3
		Rolling shear modulus (mean value)	$G_{R,mean}$	50 N/mm^2
	For references regarding the calculation see annexes 4 to 5. 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.		
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	EN 1995-1-2	β_0 = 0,65 mm/min β_n = 0,7 mm/min	
3	**Hygiene, health and the environment**			
	Vapour permeability μ	No performance assessed		
	Content of dangerous substances	EAD 130005-00-0340	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 insulation	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		
	Thermal inertia c_p	No performance assessed		

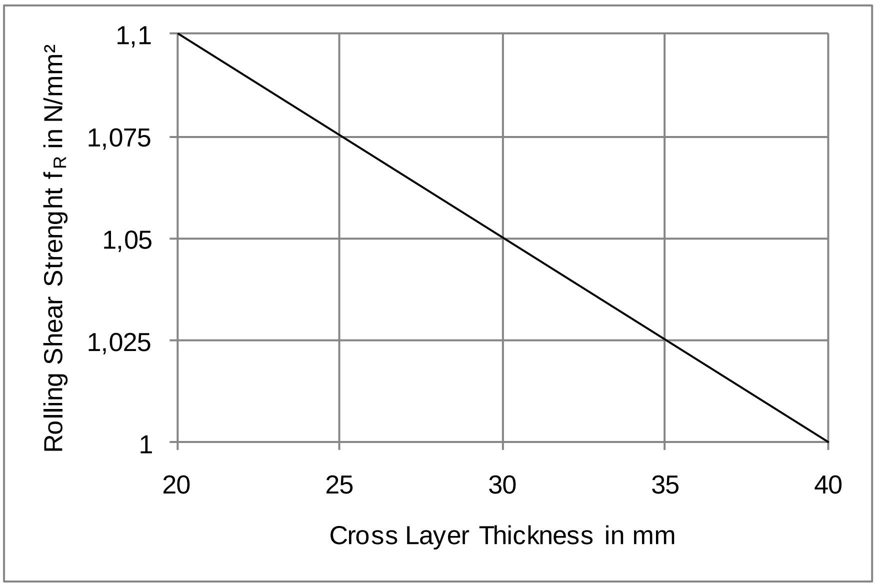


Figure 3: Rolling Shear Strength f_R

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
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	**60**	40	**60**							1,8
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**			2,2
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**	2,7

Annex 4
Design of the cross laminated timber

1 Mechanical actions perpendicular to the cross laminated timber

Stress distribution within the cross laminated timber has to 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 as mechanically jointed beam where the value s_i/K_i is substituted by $d_i/(G\ b)$ with d_i = thickness of the cross layer, G = shear modulus of the cross layer (50 N/mm^2) and b = width of the cross layer.
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, axial stresses in the center of the boards are not considered in the design.

In bending design the characteristic bending strength properties 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 element should be avoided.

2 Mechanical actions in plane of the cross laminated timber

Stress distribution within the element has to 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 width of the cross laminated timber.

For the design of cross laminated timber elements made of layers of softwood the characteristic strength and stiffness values of the layers of softwood 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.

Annex 5
Design of connections with mechanical fasteners

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 Laterally 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
- 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)

$$n_{ef} = n \qquad (1)$$

Fo outer layers with a thickness t_{lay} > 40 mm the effective number of fasteners n_{ef} for solid timber 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.

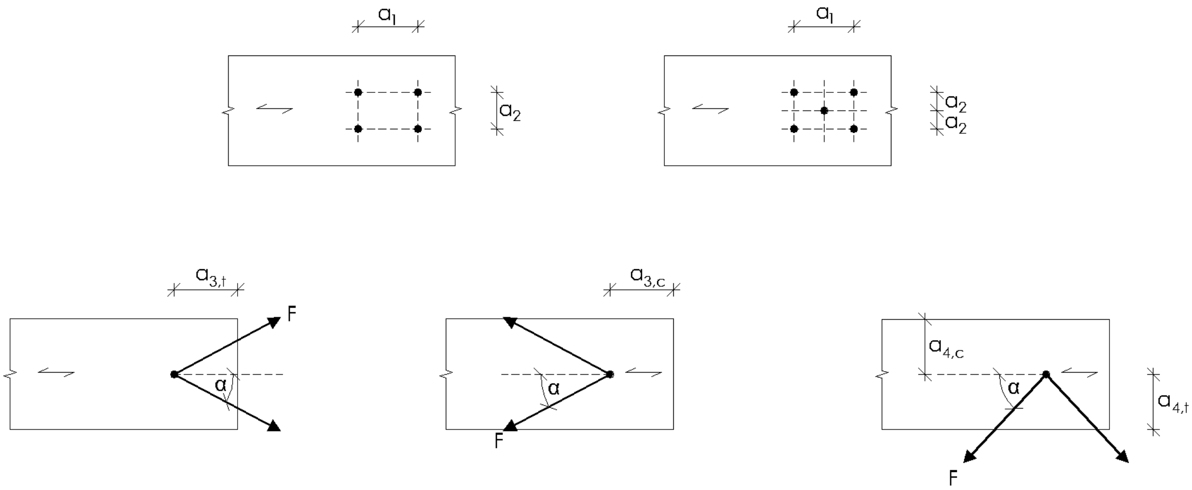


Figure 4: Definition of minimum spacings, edge and end distances for laterally loaded dowel-type fasteners in the plane side of cross laminated timber

Table 4: Definition of minimum spacings, edge and end distances in the plane side of Merkle X-Lam cross laminated timber

	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*
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	$\max\begin{cases}(3+2\cos\alpha)d\\4d\end{cases}$	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 $d \geq 8$ mm in the narrow sides of cross laminated timber may be calculated according to equation (2).

$$f_{h,k} = 20 d^{-0,5} \quad \text{in N/mm}^2 \tag{2}$$

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

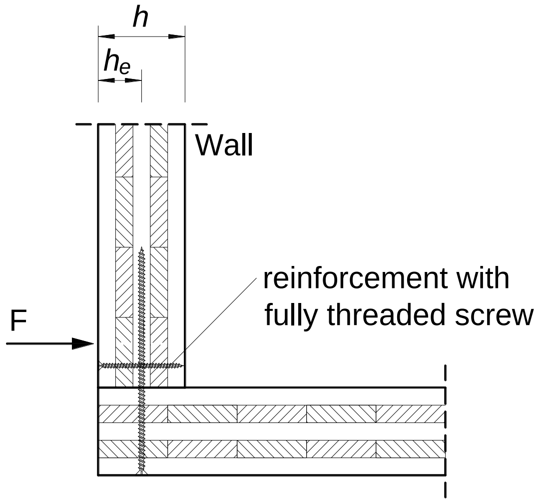


Figure 5: Reinforcement of a cross laminated timber wall with fully threaded screws

Effective number of fasteners:

The effective number of fasteners n_{ef} for solid timber may be used.

Minimum spacing, edge and end distances:

Minimum spacing, 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.

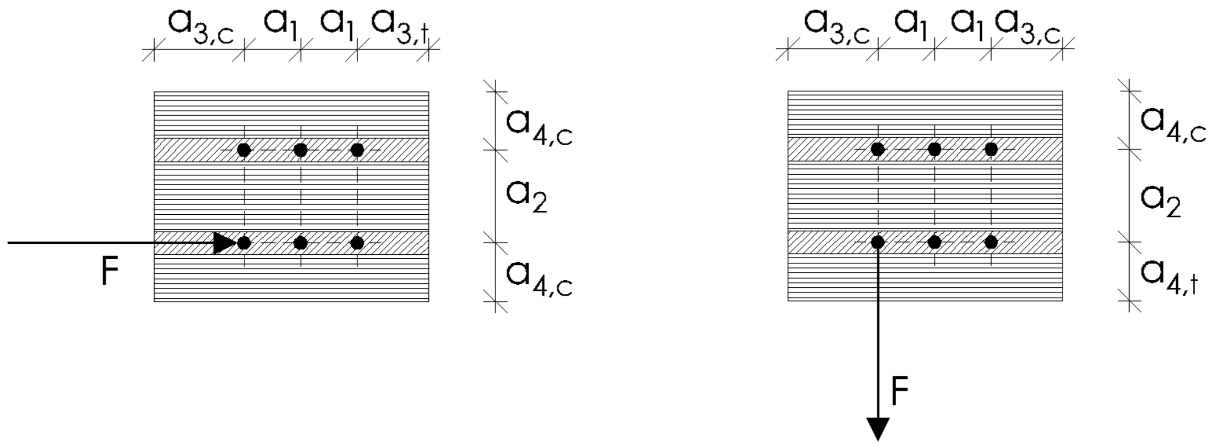


Figure 6: Definition of minimum spacings, edge and end distances for laterally loaded dowel-type fasteners in the narrow side of cross laminated timber

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

	a_1	$a_{3,t}$	$a_{3,c}$	a_2	$a_{4,t}$	$a_{4,c}$
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_{lay} in mm	Minimum thickness of the cross laminated timber t_x in mm	Minimum penetration length of the fastener t_1 or t_2 in mm [a)]
Screws	$d > 8$ mm: $3 \cdot d$ $d \leq 8$ mm: $2 \cdot d$	$10 \cdot d$	$10 \cdot d$
a) t_1 Minimum penetration length of the fastener in side members t_2 Minimum penetration length of the fastener in middle members			

1.2 Axially loaded dowel type fasteners

1.2.1 Threaded nails

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

$$F_{ax,Rk} = 14 d^{0,6} \cdot \ell_{ef} \quad \text{in N} \tag{3}$$

Where

d = Outer diameter of the threaded part

$\ell_{ef,i}$ = 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 $\geq$ 4 mm
- Penetration length of the threaded part $\ell_{ef} \geq 8\ d$
- Characteristic point side withdrawal parameter $f_{ax,k} \geq 4{,}5$ N/mm²

1.2.2 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).

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

Where

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

$f_{ax,i,k}$ = Characteristic withdrawal strength 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 $\ell_{ef,i} \geq 4\,d$

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 lamination at the head side of the screw.

Pushing-in capacity:

The characteristic pushing-in capacity for screws may be calculated according equation (5).

$$R_{ki,k} = \kappa_c \cdot N_{pl,k} \qquad \text{in N} \qquad (5)$$

Where

$$\kappa_c = \begin{cases} 1 & \text{when } \bar{\lambda}_k \leq 0,2 \\ \dfrac{1}{k + \sqrt{k^2 - \bar{\lambda}_k^2}} & \text{when } \bar{\lambda}_k > 0,2 \end{cases}$$

$$k = 0,5 \cdot \left[1 + 0,49 \cdot (\bar{\lambda}_k - 0,2) + \bar{\lambda}_k^2\right]$$

$$\bar{\lambda}_k = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}}$$

$$N_{pl,k} = \pi \cdot \frac{d_k^2}{4} \cdot f_{y,k} \text{ in N}$$

d_k = core diameter of the screw in mm

$f_{y,k}$ = yield strength in N/mm²

$N_{ki,k} = \sqrt{c_h \cdot E_S \cdot I_S}$ = buckling load of the screw in N

$c_h = (0,19 + 0,012 \cdot d) \cdot \rho_k \cdot \left(\dfrac{90° + \alpha}{180°}\right)$ = bedding factor in N/mm², the most adverse combination of α and ρ_k is relevant

ρ_k = characteristic density of a layer

α = angle between screw axis and grain direction in a layer

$E_S \cdot I_S = \dfrac{210000 \cdot \pi \cdot d_k^4}{64}$ = bending stiffness of the screws core area in N/mm²

1.3 Connections with split ring connectors and toothed-plate connectors

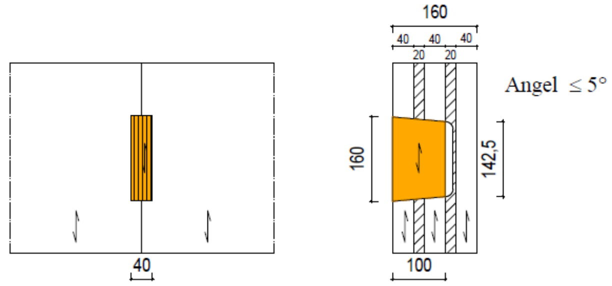
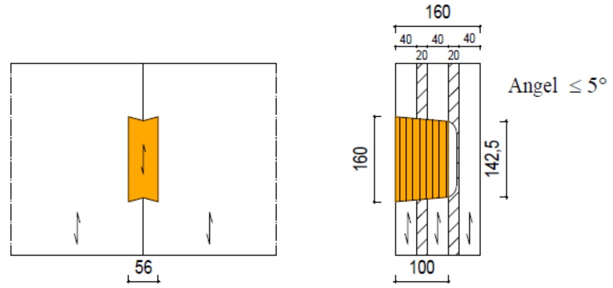
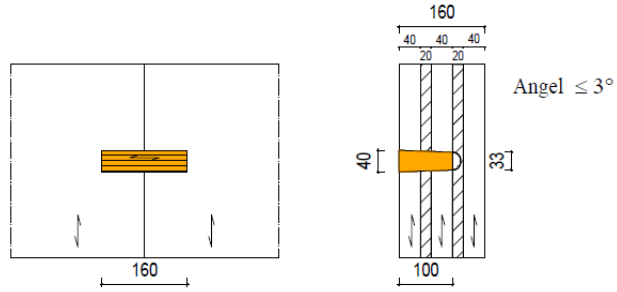
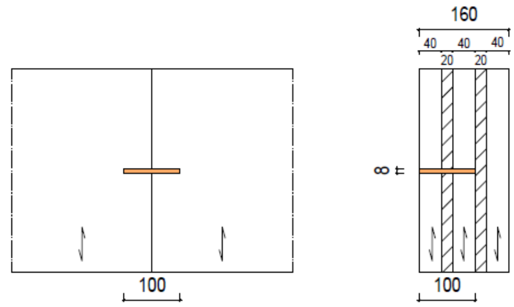
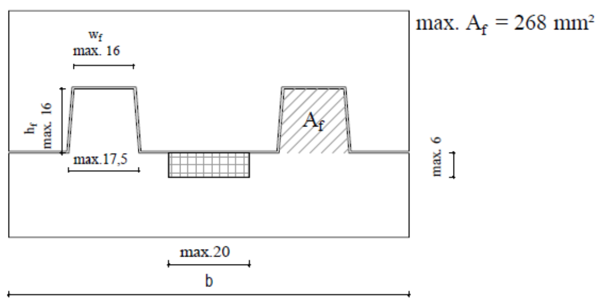
The characteristic value of the load-bearing capacity of split ring connectors and toothed-plate connectors in the plane sides of cross laminated timber may be calculated according to EN 1995-1-1.

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.

1.4 Connections with Merkle XL-Connect®

The characteristic value of the load-bearing capacity of edge connections with Merkle XL-Connect® in the narrow sides of cross laminated timber may be calculated as follows. The Beech LVL connectors are produced from LVL with characteristic density $\rho_k \geq 730$ kg/m³. The CLT edges are straight as in a butt joint or profiled.

Table 7: Types of Merkle XL-Connect®, here type 100 in Merkle X-Lam 160 mm

Merkle XL-Connect® L 100 Shear connector made of 40 mm thick Beech LVL without cross veneers according to EN 14374 with veneers oriented perpendicular to the CLT surface	
Merkle XL-Connect® X 100 Shear connector made of Beech LVL with cross veneers according to EN 14374 with veneers oriented parallel to the CLT surface	
Merkle XL-Connect® Q 100 Shear connector made of 25 mm to 40 mm thick Beech LVL without cross veneers according to EN 14374 with veneers oriented perpendicular to the CLT surface	
Merkle XL-Connect® S 100 Shear connector made of 8 mm S235JR or S355JR steel plate	
Shape of profiled CLT edge with groove cut for sealing tape	

Merkle XL-Connect® L or X

Merkle XL-Connect® L are shear keys produced from 40 mm thick Beech LVL without cross layers according to EN 14374 with characteristic density $\rho_k \geq 730$ kg/m³. The veneers are oriented perpendicular to the CLT plane sides. The end grain edges are parallel or conical with an inclination up to 5°.

Merkle XL-Connect® X are double dovetail shear keys produced from 56 mm wide Beech LVL with cross layers according to EN 14374 with characteristic density $\rho_k \geq 730$ kg/m³. The veneers are oriented parallel to the CLT plane sides. The double dovetail end grain edges are parallel or conical with an inclination up to 5°.

Characteristic load-carrying capacity:

The characteristic load-carrying capacity for Merkle XL-Connect® L or X in the narrow sides of cross laminated timber may be calculated according to equation (6).

$$F_{v,Rk} = \min \begin{cases} d \cdot \ell_c \cdot f_{v,k,LVL} \\ d \cdot \left(\min\left\{ a_1 - \ell_c ; a_{3,t} - 0{,}5 \cdot \ell_c \right\} \right) \cdot f_{v,k,CLT} \\ (0{,}5 \cdot \sum d_0 \cdot t - n \cdot A_f) \cdot f_{c,0,k} \end{cases} \qquad (6)$$

Due to the eccentricity of the compressive forces on the fastener, a tensile force $F_{t,90,k}$ perpendicular to the shear plane needs to be transferred by additional fasteners for Merkle XL-Connect® L:

$$F_{t,90,k} = \frac{3 \cdot F_{v,Ed} \cdot t}{4 \cdot \ell_c} \qquad (7)$$

Where

d width of Merkle XL-Connect® L or X perpendicular to the plane CLT member surface;

ℓ_c length of Merkle XL-Connect® L or X, $\ell_c \geq 160$ mm for Merkle XL-Connect® L, $\ell_c \geq 140$ mm for Merkle XL-Connect® X;

a_1 spacing of Merkle XL-Connect® L or X parallel to the shear plane;

$a_{3,t}$ loaded end distance of Merkle XL-Connect® L or X parallel to the shear plane;

$\Sigma d0$ accumulated layer thickness parallel to the shear plane of CLT member within width d;

t connector thickness perpendicular to the shear plane, t = 40 mm for Merkle XL-Connect® L, t = 56 mm for Merkle XL-Connect® X;

A_f cross-section of a finger in profiled member edges. Plane member edges: $A_f = 0$, profiled member edges see shaded area in Table 7: max $A_f = 268$ mm²

w_f width of fingertip in profiled member edges. For plane member edges: $w_f = 0$, for profiled member edges according to Table 7: $w_f = 16$ mm;

$f_{v,k,LVL}$ Shear strength of Beech LVL for shear failure parallel to the shear plane;

$f_{v,k,CLT}$ In plane shear strength of CLT member, see Annex 3 Table 3;

$f_{c,0,k}$ Parallel to grain compressive strength of CLT layers parallel to the shear plane. In service class 1, $f_{c,0,k}$ may be increased by 1/3;

$F_{v,Ed}$ Shear force transferred by a single Merkle XL-Connect® L.

n Number of fixings in the area of the Merkle XL-Connect® L or X

Slip modulus:

The slip modulus for Merkle XL-Connect® L or X in the narrow sides of cross laminated timber is:

$$K_{ser} = \frac{F_{v,Rk}}{1\text{mm}} \qquad (8)$$

1.4.1 Merkle XL-Connect® Q

Merkle XL-Connect® Q are shear keys produced from 25 mm to 40 mm thick Beech LVL without cross layers according to EN 14374 with characteristic density $\rho_k \geq 730$ kg/m³. The veneers are oriented perpendicular to the CLT plane sides. The long sides of the shear keys are oriented perpendicular to the shear plane between the CLT members. The end grain edges are parallel.

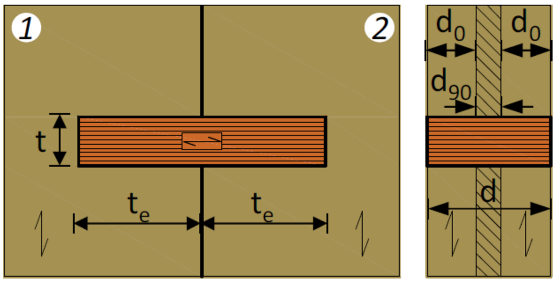


Figure 7: Merkle XL-Connect® type Q in the narrow side of CLT members

Characteristic load-carrying capacity:

The characteristic load-carrying capacity for Merkle XL-Connect® Q with minimum penetration depth $t_e = 2 \cdot t$ in the narrow sides of cross laminated timber may be calculated according to equation (9).

$$F_{v,Rk} = 1{,}7 \cdot \sum d_0 \cdot t \cdot f_{c,90,k} \qquad (9)$$

Where

t_e	penetration depth of Merkle XL-Connect® Q in both CLT members;
Σd0	accumulated layer thickness parallel to the shear plane of CLT member within width d;
t	average connector thickness perpendicular to the shear plane, 25 mm ≤ t ≤ 40 mm;
d	width of Merkle XL-Connect® Q perpendicular to the plane CLT member surface;
a_1	spacing of Merkle XL-Connect® Q parallel to the shear plane, $a_1 \geq 10 \cdot t$;
$a_{3,t}$	loaded end distance of Merkle XL-Connect® Q parallel to the shear plane, $a_{3,t} \geq 10 \cdot t$;
$f_{c,90,k}$	Perpendicular to grain compressive strength of Beech LVL.

Slip modulus:

The slip modulus for Merkle XL-Connect® Q in the narrow sides of cross laminated timber is:

$$K_{ser} = \frac{F_{v,Rk}}{2{,}5\,\text{mm}} \qquad (10)$$

1.4.2 Merkle XL-Connect® S

Merkle XL-Connect® S are rectangular steel plate fasteners produced from 6 mm to 10 mm thick mild steel plates S235JR or S355JR with or without gap. The long sides of the steel plate fasteners are oriented perpendicular to the shear plane between the CLT members. The ratio t_{gap}/t does not exceed 10.

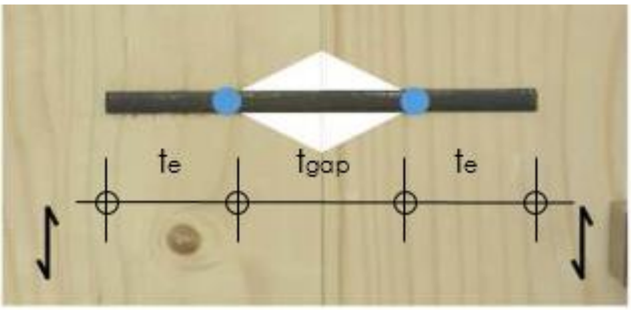


Figure 8: Merkle XL-Connect® type S with gap in the narrow sides of CLT members

Characteristic load-carrying capacity:

The characteristic load-carrying capacity for Merkle XL-Connect® S with minimum penetration depth $t_{e,min}$ in the narrow sides of cross laminated timber may be calculated according to equation (11).

$$F_{v,Rk} = \sum d_0 \cdot f_{c,0,k} \cdot \left(\sqrt{\frac{t_{gap}^2}{4} + \frac{2 \cdot M_{u,k}}{\sum d_0 \cdot f_{c,0,k}}} - \frac{t_{gap}}{2} \right) \quad (11)$$

Where
Penetration depth of Merkle XL-Connect® S in both CLT members (see Fig. 8);

$$t_e \geq \sqrt{\frac{4 \cdot M_{u,k}}{\sum d_0 \cdot f_{c,0,k}}} + \sqrt{4 \cdot t_{gap}^2 + \frac{2 \cdot M_{u,k}}{\sum d_0 \cdot f_{c,0,k}}} \quad (12)$$

Σd0 accumulated layer thickness parallel to the shear plane of CLT member within width d;
t steel plate thickness perpendicular to the shear plane, 6 mm ≤ t ≤ 10 mm;
t_e steel plate penetration depth;
d width of Merkle XL-Connect® S perpendicular to the plane CLT member surface;
a_1 spacing of Merkle XL-Connect® S parallel to the shear plane, $a_1 \geq 40 \cdot t$;
$a_{3,t}$ loaded end distance of Merkle XL-Connect® Q parallel to the shear plane, $a_{3,t} \geq 40 \cdot t$;
$f_{c,0,k}$ Parallel to grain compressive strength of CLT layers parallel to the shear plane. In service class 1, $f_{c,0,k}$ may be increased by 1/3;
$M_{u,k}$ Steel plate plastic bending moment, $M_{u,k} = 0,25 \cdot f_{u,k} \cdot d \cdot t^2$
$f_{u,k}$ Characteristic steel tensile strength.

Slip modulus:

The slip modulus for Merkle XL-Connect® S in the narrow sides of cross laminated timber is:

$$K_{ser} = \frac{F_{v,Rk}}{(1{,}3 + 0{,}3 \cdot t_{gap} / t)\,mm} \quad (13)$$

Static ductility:
The static ductility ratio of Merkle XL-Connect® type S used as edge fasteners in CLT shear walls exceeds 6. Consequently, ductility class DCH may be assumed in the design of these structures under earthquake loading.

Annex 6
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 si/Ki according to the standard is substituted by the factor $\overline{h}_i / (G_R \cdot b)$.

The effective moment of inertia is calculated by:

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

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

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

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

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.

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

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

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

Legend:

h_{tot}	=	thickness of the whole element [mm]
h_i	=	thickness of the layer i parallel to the direction of load transfer [mm]
$\overline{h}_i$	=	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]
l_{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]