CLT – Cross Laminated Timber

Connections

Date: 21.08.2014

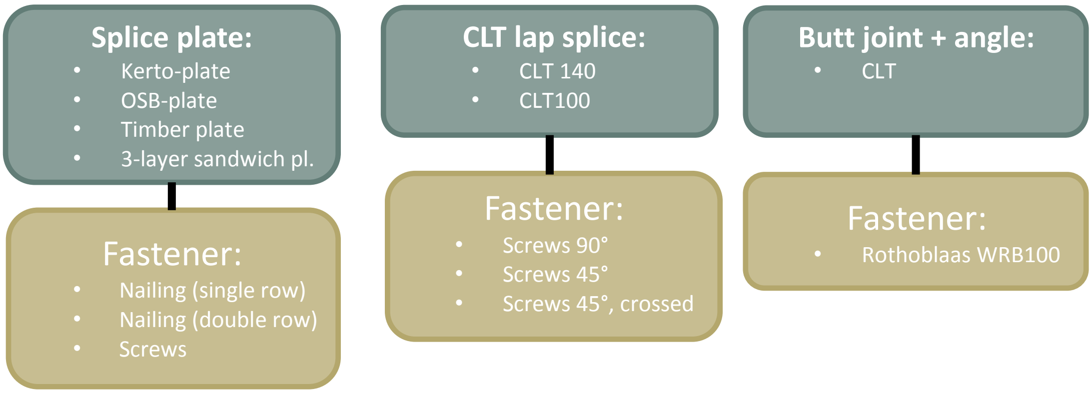
CLT connections

BUTT JOINT WITH SPLICE PLATE 08/**2014**

Disclaimer
The below presented structural analysis is an exemplified calculation. This calculation is solely a proposal for a design approach. This structural design proposal must be verified and approved regarding completeness and correctness by the project structural engineer in charge. Stora Enso Wood Products GmbH excludes all liability for the completeness or correctness of the analysis below. The project structural engineer is not allowed to use the calculation towards third parties. For further use in the project he has to produce his independent calculation. The below calculation does not constitute any warranty or representation for the product Cross-Laminated-Timber.

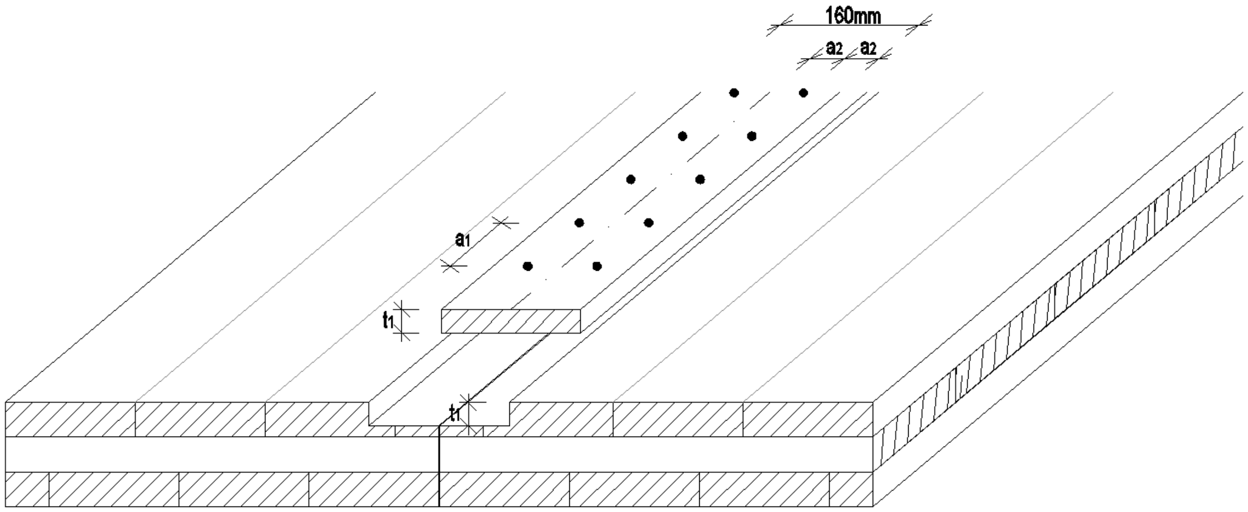
Connection design for CLT walls and slabs

The present document shall provide a review of the most common CLT connection systems. This includes some design tables with graphs along with the analytical calculation of the design values, which shall help the reader to verify the design values and understand the provided connection analysis.
The design was performed, according to EN 1995-1-1.

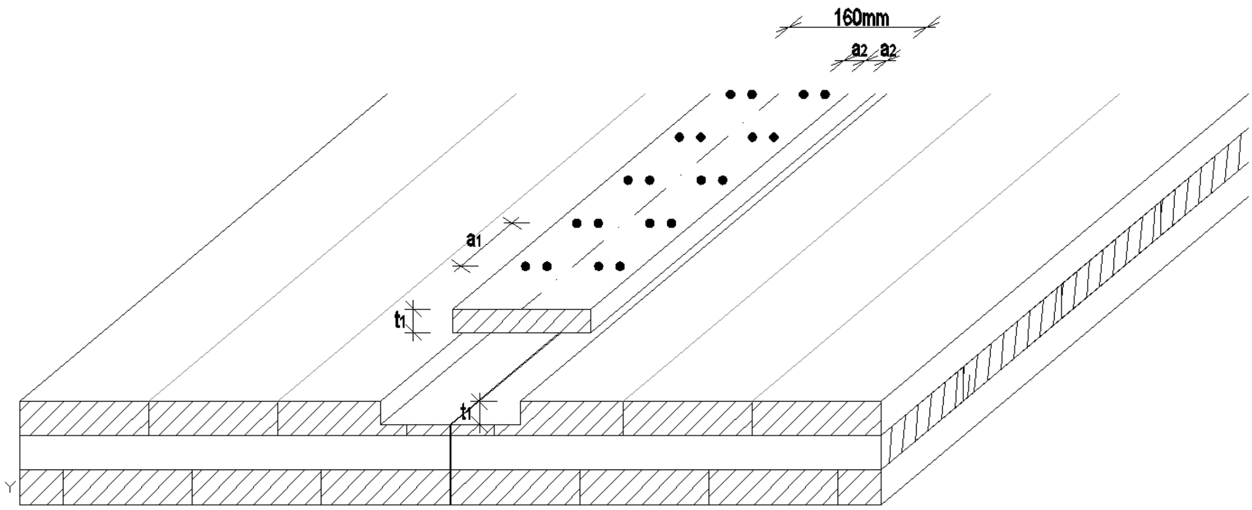


ENGINEERED WOOD CONSTRUCTION
CLT-S

1 Butt joint with splice board - nailed



Nailing (single row)



Nailing (double row)

1.1 Kerto – CLT

Members	ρ_k [kg/m³]	t_i [mm]
1 - Kerto	480	27
2 - CLT	350	>80

Fastener	Ø [mm]	L [mm]
Nail (common)	2,7	70

1.1.1 Characteristic embedment strength

(see approval Z-9.1-559 from DIBt & ETA-08/0271)

1.1.2 Yield moment of the nail

1.1.3 Characteristic point side withdrawal strength of the nail

1.1.4 Characteristic shear capacity of the nail

1.1.5 Design shear capacity of the nail

1.1.6 Minimum embedment depth

1.1.7 Minimum spacing and edge distance

$$85 \cdot (7 + 8 \cdot \cos\alpha) \cdot d = 0{,}85 \cdot (7 + 8 \cdot 1)$$

1.2 OSB – CLT

Members	ρ_k [kg/m³]	t_i [mm]
1 - OSB	550	25
2 - CLT	350	>80

Fastener	Ø [mm]	L [mm]
Nail (common)	2,7	70

Note: the standard splice board depth is 27mm. Since OSB boards are not available in a thickness of 27mm, a 25mm OSB-plate is being used.

1.2.1 Characteristic embedment strength

(see approval Z-9.1-559 from DIBt & ETA-08/0271)

1.2.2 Yield moment of the nail

1.2.3 Characteristic point side withdrawal strength of the nail

1.2.4 Characteristic shear capacity of the nail

$$\sqrt{\quad} \quad \sqrt{2 \quad}$$

$$\sqrt{\quad} \quad \sqrt{2 \quad}$$

$$\sqrt{\quad} \quad \sqrt{0 \quad}$$

CLT connections

1.2.5 Design shear capacity of the nail

1.2.6 Minimum embedment depth

$$\left(2 \cdot \sqrt{} \right) \cdot \sqrt{}$$

$$\left(2 \cdot \sqrt{} \right) \cdot \sqrt{}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \right) \cdot \sqrt{}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \right) \cdot \sqrt{}$$

1.2.7 Minimum spacing and edge distance

$$85 \cdot (7 + 8 \cdot \cos\alpha) \cdot d = 0{,}85 \cdot (7 + 8 \cdot 1)$$

1.3 Splice plate (spruce) – CLT

Members	ρ_k [kg/m³]	t_i [mm]
1 – splice plate	350	27
2 - CLT	350	>80

Fastener	Ø [mm]	L [mm]
Nail (common)	2,7	70

1.3.1 Characteristic embedment strength

(see approval Z-9.1-559 from DIBt & ETA-08/0271)

1.3.2 Yield moment of the nail

1.3.3 Characteristic point side withdrawal strength of the nail

1.3.4 Characteristic shear capacity of the nail

1.3.5 Design shear capacity of the nail

$$\frac{}{} \quad \frac{}{}$$

1.3.6 Minimum embedment depth

$$\left(2 \cdot \sqrt{\frac{}{}} \quad \right) \cdot \sqrt{\frac{}{}}$$

$$\left(2 \cdot \sqrt{\frac{}{}} \quad \right) \cdot \sqrt{\frac{}{}}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \quad \right) \cdot \sqrt{\frac{}{}}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \quad \right) \cdot \sqrt{\frac{}{}}$$

1.3.7 Minimum spacing and edge distance

$$(5 \quad \alpha) \cdot d = (5 + 5 \cdot 1)$$

ENGINEERED WOOD CONSTRUCTION
CLT-S

1.4 3-layer sandwich plate – CLT

Bauteile	ρ_k [kg/m³]	t_i [mm]
1 – 3-layer sand-wich plate	410	27
2 - CLT	350	>80

Fasteener	Ø [mm]	L [mm]
Nail (common)	2,7	70

1.4.1 Characteristic embedment strength

(see approval Z-9.1-559 from DIBt & ETA-08/0271)

1.4.2 Yield moment of the nail

1.4.3 Characteristic point side withdrawal strength of the nail

1.4.4 Characteristic shear capacity of the nail

$\sqrt{2}$

$\sqrt{2}$

$\sqrt{0}$

ENGINEERED WOOD CONSTRUCTION CLT-S

CLT connections

1.4.5 Design shear capacity of the nail

1.4.6 Minimum embedment depth

$$\left(2 \cdot \sqrt{} \quad\right) \cdot \sqrt{}$$

$$\left(2 \cdot \sqrt{} \quad\right) \cdot \sqrt{}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \quad\right) \cdot \sqrt{}$$

$$\left(2 \cdot \frac{}{\sqrt{1}} \quad\right) \cdot \sqrt{}$$

1.4.7 Minimum spacing and edge distance

$$(5 \qquad \alpha) \cdot d = (5 + 5 \cdot 1)$$

ENGINEERED
WOOD CONSTRUCTION
CLT-S

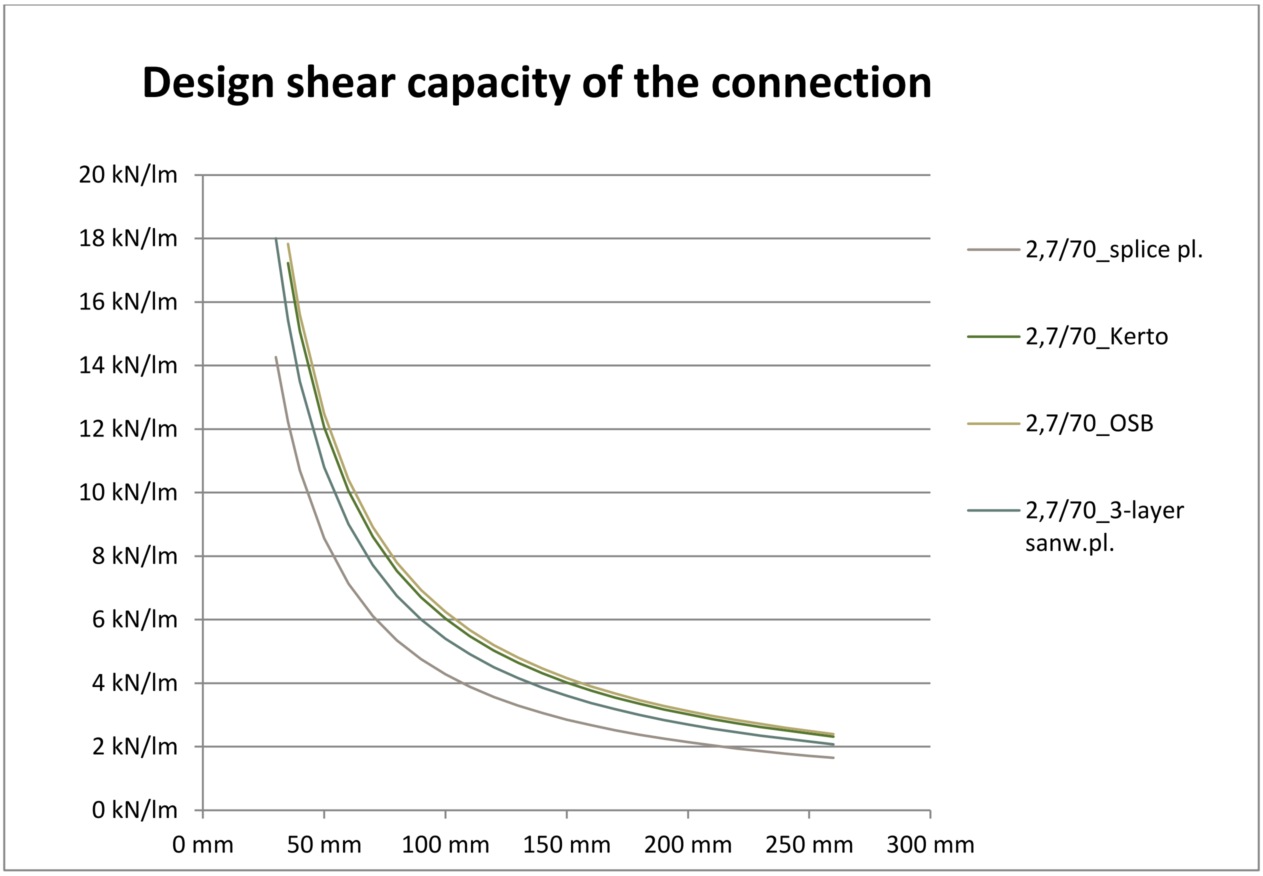
Butt joint with splice plate

Nailing (single row) Ø2,7/70

CLT spruce / fir (C24)

k_{mod} = 0,9

	Splice pl. (spruce) 27mm	3-layer sandwich pl. 27mm	Kerto 27mm	OSB 25mm
Nail spacing	Ø 2,7 / 70	Ø 2,7 / 70	Ø 2,7 / 70	Ø 2,7 / 70
a_1	$F_{v,RD}$	$F_{v,RD}$	$F_{v,RD}$	$F_{v,RD}$
	[kN/lm]	[kN/lm]	[kN/lm]	[kN/lm]
30 mm	14,27	18,00		
35 mm	12,23	15,43	17,23	17,83
40 mm	10,70	13,50	15,08	15,60
50 mm	8,56	10,80	12,06	12,48
60 mm	7,13	9,00	10,05	10,40
70 mm	6,11	7,71	8,61	8,91
80 mm	5,35	6,75	7,54	7,80
90 mm	4,76	6,00	6,70	6,93
100 mm	4,28	5,40	6,03	6,24
110 mm	3,89	4,91	5,48	5,67
120 mm	3,57	4,50	5,03	5,20
130 mm	3,29	4,15	4,64	4,80
140 mm	3,06	3,86	4,31	4,46
150 mm	2,85	3,60	4,02	4,16
160 mm	2,68	3,38	3,77	3,90
170 mm	2,52	3,18	3,55	3,67
180 mm	2,38	3,00	3,35	3,47
190 mm	2,25	2,84	3,17	3,28
200 mm	2,14	2,70	3,02	3,12
210 mm	2,04	2,57	2,87	2,97
220 mm	1,95	2,45	2,74	2,84
230 mm	1,86	2,35	2,62	2,71
240 mm	1,78	2,25	2,51	2,60
250 mm	1,71	2,16	2,41	2,50
260 mm	1,65	2,08	2,32	2,40


Design shear capacity of the connection
20 kN/lm
18 kN/lm
16 kN/lm
14 kN/lm
12 kN/lm
10 kN/lm
8 kN/lm
6 kN/lm
4 kN/lm
2 kN/lm
0 kN/lm
0 mm
50 mm
100 mm
150 mm
200 mm
250 mm
300 mm
2,7/70_splice pl.
2,7/70_Kerto
2,7/70_OSB
2,7/70_3-layer sanw.pl.

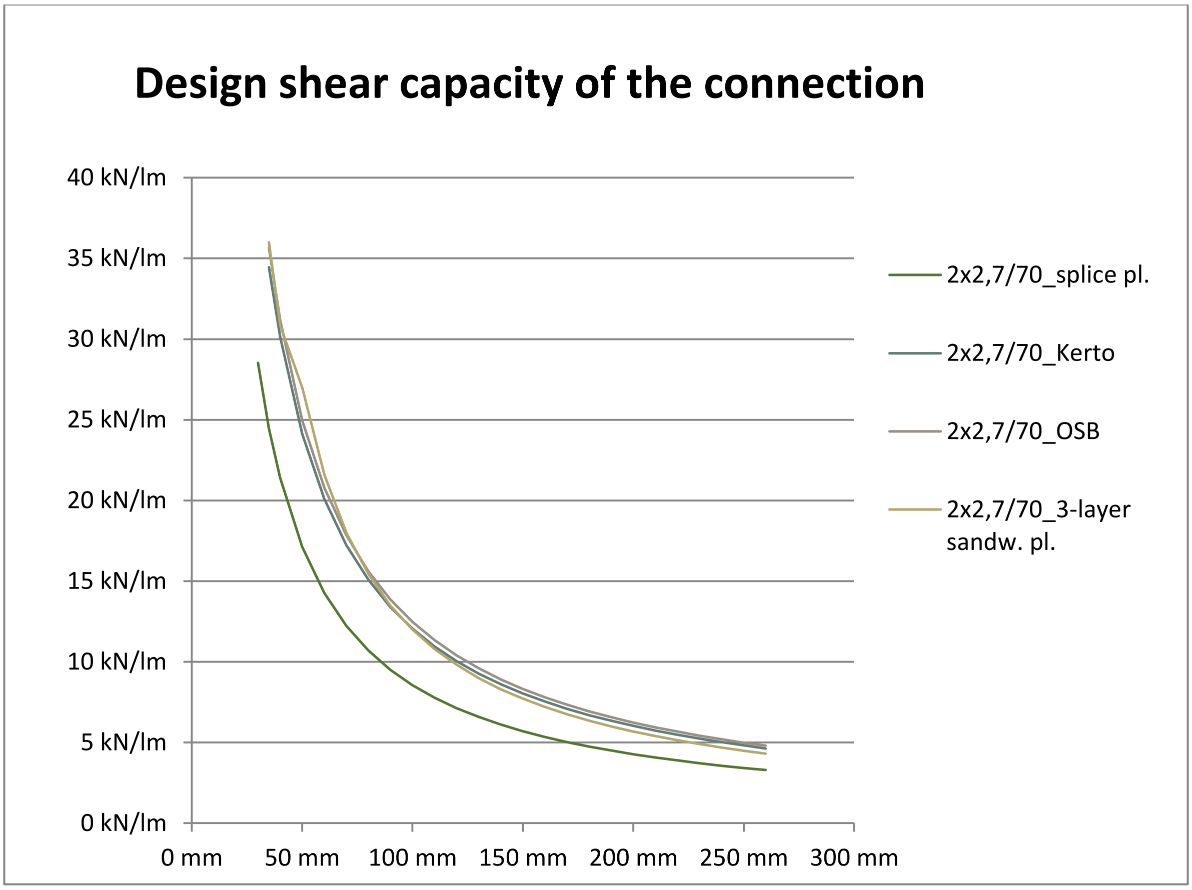
Butt joint with splice plate

Nailing (double row) Ø2,7/70

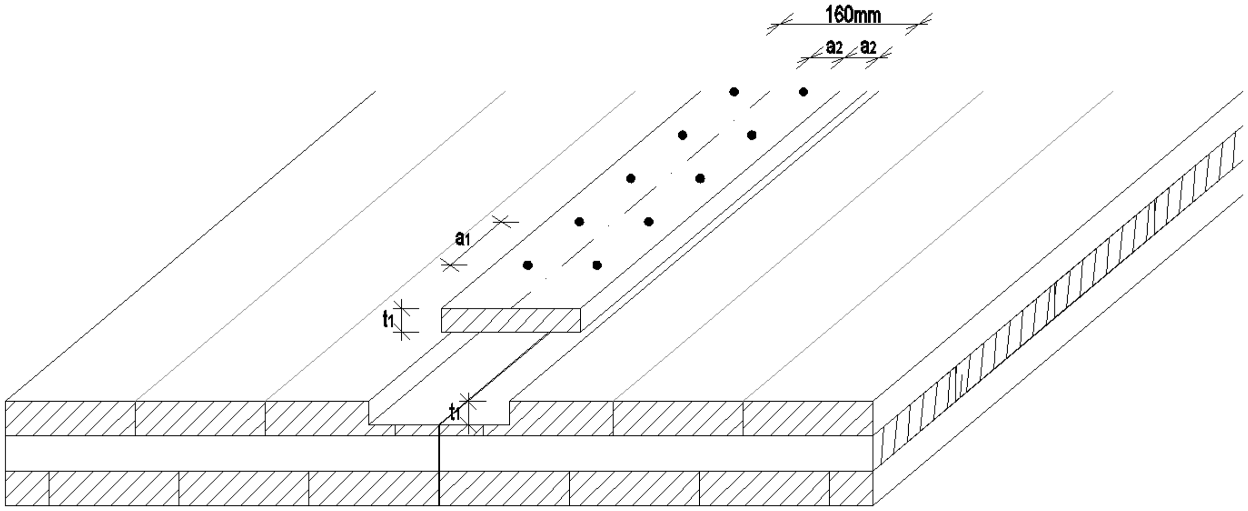
CLT spruce / fir (C24)

k_{mod} = 0,9

	Splice pl. (spruce) 27mm	3-layer sand-wich pl. 27mm	Kerto 27mm	OSB 25mm
Nail spacing	2x Ø 2,7 / 70	2x Ø 2,7 / 70	2x Ø 2,7 / 70	2x Ø 2,7 / 70
a_1	$F_{v,RD}$	$F_{v,RD}$	$F_{v,RD}$	$F_{v,RD}$
	[kN/lm]	[kN/lm]	[kN/lm]	[kN/lm]
30 mm	28,53	36,00		
35 mm	24,46	30,86	34,46	35,66
40 mm	21,40	27,00	30,15	31,20
50 mm	17,12	21,60	24,12	24,96
60 mm	14,27	18,00	20,10	20,80
70 mm	12,23	15,43	17,23	17,83
80 mm	10,70	13,50	15,08	15,60
90 mm	9,51	12,00	13,40	13,87
100 mm	8,56	10,80	12,06	12,48
110 mm	7,78	9,82	10,96	11,35
120 mm	7,13	9,00	10,05	10,40
130 mm	6,58	8,31	9,28	9,60
140 mm	6,11	7,71	8,61	8,91
150 mm	5,71	7,20	8,04	8,32
160 mm	5,35	6,75	7,54	7,80
170 mm	5,04	6,35	7,09	7,34
180 mm	4,76	6,00	6,70	6,93
190 mm	4,51	5,68	6,35	6,57
200 mm	4,28	5,40	6,03	6,24
210 mm	4,08	5,14	5,74	5,94
220 mm	3,89	4,91	5,48	5,67
230 mm	3,72	4,70	5,24	5,43
240 mm	3,57	4,50	5,03	5,20
250 mm	3,42	4,32	4,82	4,99
260 mm	3,29	4,15	4,64	4,80


Design shear capacity of the connection
40 kN/lm
35 kN/lm
30 kN/lm
25 kN/lm
20 kN/lm
15 kN/lm
10 kN/lm
5 kN/lm
0 kN/lm
0 mm
50 mm
100 mm
150 mm
200 mm
250 mm
300 mm
2x2,7/70_splice pl.
2x2,7/70_Kerto
2x2,7/70_OSB
2x2,7/70_3-layer sandw. pl.

2 Splice plate - screwed



2.1 3-layer sandwich plate – CLT

Members	ρ_k [kg/m³]	t_i [mm]
1 – 3-layer sand-wich plate	410	45
2 - CLT	350	>80

Fastener	d_1 [mm]	d_S [mm]	d_2 [mm]	d_{ef} [mm]
Screws Rothoblaas HBS 6x100	6,0	4,3	3,95	4,35

2.1.1 Characteristic embedment strength

(see approval Z-9.1-559 from DIBt & ETA-08/0271)

According to technical approval DIBt Z-9.1-731: for Rothoblaas partial threaded screws, the external thread diameter d_1 is design relevant.

2.1.2 Yield moment of the screw

$m\ (acc \quad 731)$

2.1.3 Characteristic shear capacity of the screw

Note: the characteristic shear capacity shall be calculated according to the applicable technical approvals and/or according to the rules in EN1995-1-1. Generally (and according to EN1995-1-1) it would be possible to include the component with a fraction of the withdrawal strength (cable effect) which would increase the capacity. See EN1995-1-1, item 8.2.2 (1):

$$\sqrt{} \quad \sqrt{2} \qquad \frac{}{4}$$

The applicable technical approvals always need to be respected. If the technical approval does not address the characteristic shear capacity, the rules in EN1995-1-1 shall apply.

$$\sqrt{k} \qquad \sqrt{}$$

2.1.4 Design shear capacity of the screw

2.1.5 Minimum embedment depth

$$\left(2\cdot\sqrt{}\right)\cdot\sqrt{}$$

$$\left(2\cdot\sqrt{}\right)\cdot\sqrt{}$$

$$\left(2\cdot\frac{}{\sqrt{1}}\right)\cdot\sqrt{}$$

$$\left(2\cdot\frac{}{\sqrt{1}}\right)\cdot\sqrt{}$$

2.1.6 Minimum spacing and edge distance

$$(5 \quad \alpha)\cdot d = (5+7\cdot 1)$$

2.2 Kerto – CLT

Members	ρ_k [kg/m³]	t_i [mm]
1 – Kerto	480	33
2 - CLT	350	>80

Fastener	d_1 [mm]	d_S [mm]	d_2 [mm]	d_{ef} [mm]
Screws: Rothoblaas HBS 6x90	6,0	4,3	3,95	4,35

2.2.1 Characteristic embedment strength

(See approval Z-9.1-559 from DIBt & ETA-08/0271)

According to technical approval DIBt Z-9.1-731: for Rothoblaas partial threaded screws, the external thread diameter d_1 is design relevant.

2.2.2 Yield moment of the screw

$m\ (acc \quad 731)$

2.2.3 Characteristic shear capacity of the screw

$\sqrt{} \quad \sqrt{2}$

$\sqrt{} \quad \sqrt{2}$

Note: the characteristic shear capacity shall be calculated according to the applicable technical approvals and/or according to the rules in EN1995-1-1. Generally (and according to EN1995-1-1) it would be possible to include the component with a fraction of the withdrawal strength (cable effect) which would increase the capacity. See EN1995-1-1, item 8.2.2 (1):

$$\sqrt{\quad} \sqrt{2} \qquad 4$$

The applicable technical approvals always need to be respected. If the technical approval does not address the characteristic shear capacity, the rules in EN1995-1-1 shall apply.

$$\sqrt{k} \qquad \sqrt{\quad}$$

2.2.4 Design shear capacity of the screw

2.2.5 Minimum embedment depth

$$\left(2 \cdot \sqrt{\quad}\right) \cdot \sqrt{\quad}$$

$$\left(2 \cdot \sqrt{\quad}\right) \cdot \sqrt{\quad}$$

$$\left(2 \cdot \frac{}{\sqrt{1}}\right) \cdot \sqrt{\quad}$$

$$\left(2 \cdot \frac{}{\sqrt{1}}\right) \cdot \sqrt{\quad}$$

2.2.6 Minimum spacing and edge distance

$$(7 \qquad \alpha) \cdot d \cdot 0{,}85 = (7 + 8 \cdot 1)$$

ENGINEERED WOOD CONSTRUCTION

CLT-S

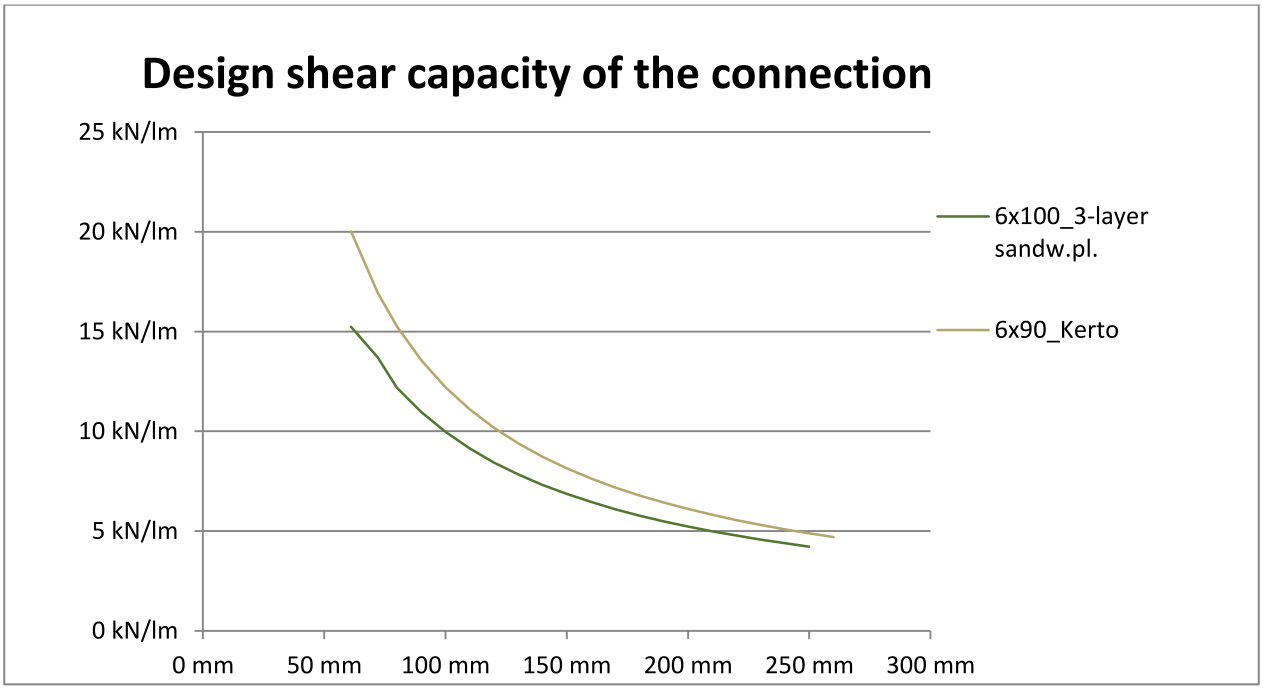
Butt joint with splice plate

Screws (single row) Ø6/xx

CLT spruce/fir (C24)

k_{mod} = 0,9

	3-layer sandwich pl. 45mm	Kerto 33mm
Screw spacing	Ø 6 / 100	Ø 6 / 90
a_1	$F_{v,RD}$	$F_{v,RD}$
	[kN/lm]	[kN/lm]
61 mm		20,02
72 mm	15,24	16,96
80 mm	13,71	15,26
90 mm	12,19	13,57
100 mm	10,97	12,21
110 mm	9,97	11,10
120 mm	9,14	10,18
130 mm	8,44	9,39
140 mm	7,84	8,72
150 mm	7,31	8,14
160 mm	6,86	7,63
170 mm	6,45	7,18
180 mm	6,09	6,78
190 mm	5,77	6,43
200 mm	5,49	6,11
210 mm	5,22	5,81
220 mm	4,99	5,55
230 mm	4,77	5,31
240 mm	4,57	5,09
250 mm	4,39	4,88
260 mm	4,22	4,70


Design shear capacity of the connection
25 kN/lm
20 kN/lm
15 kN/lm
10 kN/lm
5 kN/lm
0 kN/lm
0 mm
50 mm
100 mm
150 mm
200 mm
250 mm
300 mm
6x100_3-layer sandw.pl.
6x90_Kerto

3 Lap splice with screws

3.1 Lap splice with screws for CLT 100mm vertical screws

3.1.1 CLT:

CLT100 L3s

Wood grade according to EN338: C24

ρ_k = 350 kg/m³

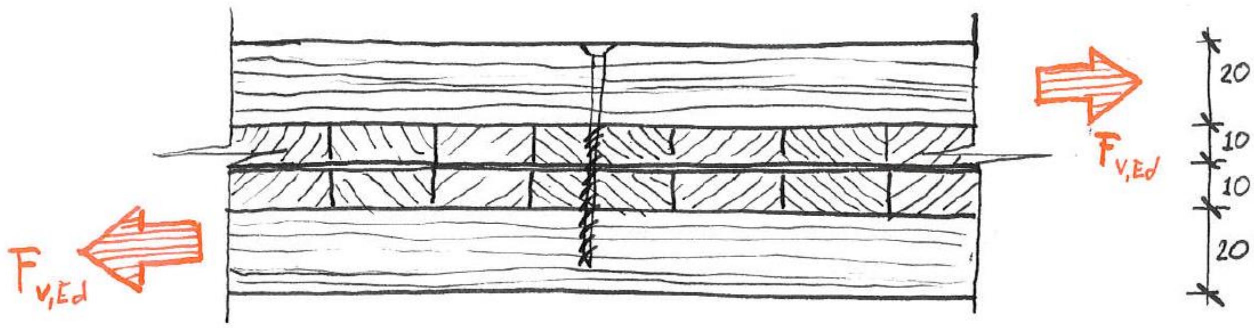
3.1.2 Screws:

Würth Assy plus partially threaded screws (counter sunk), Ø6x90

The screws shall be fastened perpendicular to the clt face.

Nominal diameter = external thread diameter d	6,00 mm
Head diameter d_{head}	14,00 mm
Core diameter = internal thread diameter d_2	3,90 mm
Shaft diameter d_s	4,40 mm
Yiled moment of the screw $M_{y,Rk}$	5.500 Nmm
Total length L_{screw}	90 mm
Threaded length L_{tr}	50 mm

3.1.3 Geometry



3.1.4 Spacing and edge distance

$$(5 \qquad \alpha) \cdot \mathrm{d} = (5 + 7\cos 0°)$$

The minimum width of the horizontal joint in the lap has to be at least the double of the minimum edge distance.

3.1.5 Shear capacity of the screw

3.1.5.1 Characteristic embedment strength

See European Technical Approval ETA-08/0271. Here the embedment strength is being determined on the base of the nominal diameter of the screw.

$$\sqrt{\frac{}{}} \quad \sqrt{2}$$

In the equation for the characteristic shear capacity of the screw, the effective diameter d_{eff} is being used See EN1995-1-1, Item 8.7.1. The effective diameter d_{eff} is less than the nominal diameter, therefore the value is on the safe side. Some technical approvals for screws allow the use of the nominal diameter of the screw.

Location of the horizontal joint of the lap, related to the head of the screw:

$$- \quad \frac{}{} \qquad (\mathrm{L} \qquad) = (90 \qquad \mathrm{mm})$$

Therefore the threaded portion of the screw is situated in the shear joint and the effective diameter of the screw derives as follows:

Since $f_{h,k,1} = f_{h,k,2} = f_{h,k}$ is $\beta=1$ and therefor:

$$\sqrt{2} \qquad \sqrt{2 \qquad \mathrm{N/m}}$$

3.1.5.2 Design shear capacity of one screw

$$\frac{}{} \quad \frac{}{}$$

Mostly seismic and wind forces are being transferred through the lap joint. Therefore k_{mod} = 0,9. According to EN1995-1-1, Table 2.3, γ_M = 1,30.

3.1.6 Design shear capacity (maximum design shear capacity per linear meter)

$$\frac{}{} \quad \frac{}{}$$

3.2 Lap splice with screws for CLT 140mm vertical screws

3.2.1 CLT:

CLT140 L5s

Wood grade according to EN338: C24

ρ_k = 350 kg/m³

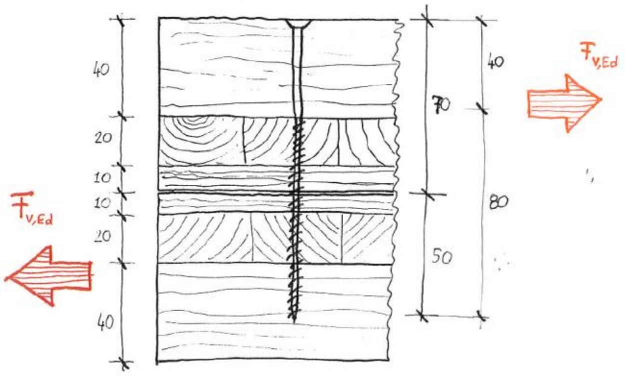
3.2.2 Screws:

Würth Assy plus partially threaded screws (counter sunk), Ø8x120

The screws shall be fastened perpendicular to the clt face.

Nominal diameter = external thread diameter d	8,00 mm
Head diameter d_{head}	15,00 mm
Core diameter = internal thread diameter d_2	5,30 mm
Shaft diameter d_s	5,80 mm
Yiled moment of the screw $M_{y,Rk}$	11.000 Nmm
Total length L_{screw}	120 mm
Threaded length L_{tr}	80 mm

3.2.3 Geometry



3.2.4 Spacing and edge distance

$(5 \qquad \alpha) \cdot d = (5 + 7\cos 0°)$

The minimum width of the horizontal joint in the lap has to be at least the double of the minimum edge distance.

3.2.5 Shear capacity of the screw

3.2.5.1 Characteristic embedment strength

See European Technical Approval ETA-08/0271. Here the embedment strength is being determined on the base of the nominal diameter of the screw.

$$\sqrt{\frac{\quad}{\quad}} \quad \sqrt{2 \qquad\qquad\qquad}$$

In the equation for the characteristic shear capacity of the screw, the effective diameter d_{eff} is being used See EN1995-1-1, Item 8.7.1. The effective diameter d_{eff} is less than the nominal diameter, therefore the value is on the safe side. Some technical approvals for screws allow the use of the nominal diameter of the screw.

Location of the horizontal joint of the lap, related to the head of the screw:

$$- \quad \frac{\quad}{\quad} \qquad (L \qquad) = (120 \qquad mm)$$

Therefore the threaded portion of the screw is situated in the shear joint and the effective diameter of the screw derives as follows:

Since $f_{h,k,1} = f_{h,k,2} = f_{h,k}$ is $\beta=1$ and therefore:

$$\sqrt{2 \qquad\qquad} \qquad \sqrt{2 \qquad\qquad\qquad N/m \qquad\qquad}$$

3.2.5.2 Design shear capacity of one screw

$$\frac{\quad}{\quad} \quad \frac{\quad}{\quad}$$

Mostly seismic and wind forces are being transferred through the lap joint. Therefore k_{mod} = 0,9. According to EN1995-1-1, Table 2.3, γ_M = 1,30.

3.2.6 Design shear capacity (maximum design shear capacity per linear meter)

$$\frac{\quad}{\quad} \quad \frac{\quad}{\quad}$$

3.3 Lap splice with screws for CLT 140mm
45° inclined screws

3.3.1 CLT:

CLT140 L5s

Wood grade according to EN338: C24

ρ_k = 350 kg/m³

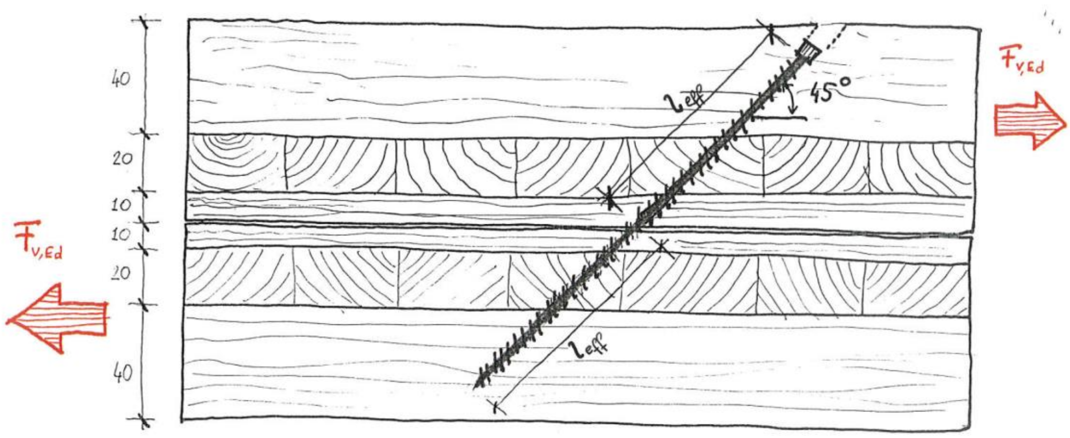
3.3.2 Screws:

Würth Assy VG plus Ø8x160

The screws shall be placed 45° inclined towards the clt face

Nominal diameter = external thread diameter d	8,00 mm
Head diameter d_{head}	10,20 mm
Core diameter = internal thread diameter d_2	5,00 mm
Yiled moment of the screw $M_{y,Rk}$	16.700 Nmm
Total length L_{screw}	160 mm
Threaded length L_{tr}	149 mm

3.3.3 Geometry



3.3.4 Spacing and edge distance

See technical approval Z-9.1-614 from DIBt.

The standard width of lap joints for CLT from Stora Enso Wood Products GmbH is 50mm. This results in an edge distance of a_2 von 25 mm.

3.3.5 Withdrawal strength of a screw

3.3.5.1 Axial withdrawal strength

For screws that penetrate more than one CLT-layer, $f_{ax,k}$ is being distributed accordingly.

In the present case, the screw shall be anchored equally in the top and bottom member of the lap, so the center of gravity of the screw is located in the joint. Hence the head of the screw needs to be sunk in the CLT. This means the screws need to penetrate the CLT $\frac{}{2\cdot\sqrt{2}}$ mm, measured from the center (vertical projected length), which equals to an actual screw length of:

$\sqrt{2}$

3.3.5.2 Characteristic point side withdrawal strength of the screw

CLT Layer	Thickness (vertical)	Screw penetration (vertical)	Screw penetration (in parallel to screw axis)	α	$F_{ax,\alpha,Rk}$
	[mm]	[mm]	[mm]	[°]	[N]
L1	40	22	31	45	2091
C12	20	20	28	90	2217
L2/1	10	10	14	45	950
Joint	0				
L2/2	10	10	14	45	950
C23	20	20	28	90	2217
L3	40	22	31	45	2091
			74		**5259**

3.3.5.3 Headside pull-through strength of the screw

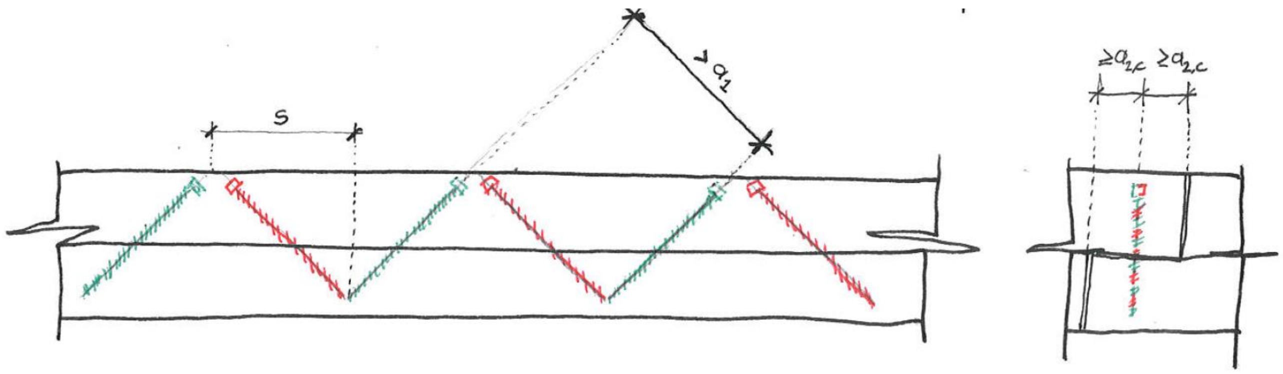
Because the joint is located in the center of gravity of the screw, point side withdrawal is governing.

3.3.5.4 Tensile strength of the screw

$F_{t,u,k}$ = 9.100 N

Point side withdrawal of the screw is governing, accordingly N.

3.3.5.5 Design withdrawal strength



3.3.6 Spacing

$$\sqrt{2} \qquad \frac{\qquad}{\sqrt{2}} \qquad \sqrt{2} \qquad \frac{}{\sqrt{2}}$$

The orientation of the placed screws is alternating 90° every other screw, so the connection can take forces in either direction.

3.3.7 Design shear capacity (maximum design shear capacity per linear meter)

$$\left(\frac{ax}{\sqrt{2}} \quad \right) \qquad \left(\frac{\qquad}{\sqrt{2}}\right) \qquad N/lm$$

3.4 Lap splice with screws for CLT 140mm 45° inclined screws, crossed

3.4.1 CLT:

CLT140 L5s

Wood grade according to EN338: C24

ρ_k = 350 kg/m³

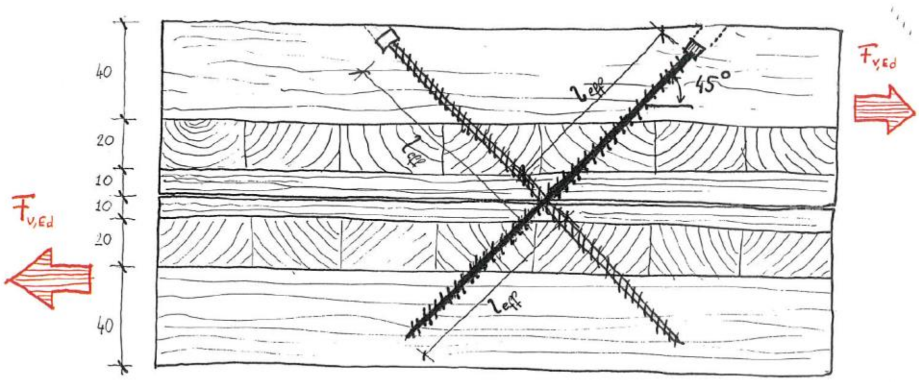
3.4.2 Screws

Würth Assy VG plus Ø8x160

The screws shall be placed 45° inclined towards the clt face and crossed

Nominal diameter = external thread diameter d	8,00 mm
Head diameter d_{head}	10,20 mm
Core diameter = internal thread diameter d_2	5,00 mm
Yiled moment of the screw $M_{y,Rk}$	16.700 Nmm
Total length L_{screw}	160 mm
Threaded length L_{tr}	149 mm

3.4.3 Geometry



3.4.4 Spacing and edge distance

See technical approval Z-9.1-614 from DIBt.

The minimum width of the horizontal joint in the lap has to be at least the double of the minimum edge distance plus required spacing perpendicular to shear direction:

3.4.5 Withdrawal strength of a screw

3.4.5.1 Axial withdrawal strength

For screws that penetrate more than one CLT-layer, $f_{ax,k}$ is being distributed accordingly.

In the present case, the screw shall be anchored equally in the top and bottom member of the lap, so the center of gravity of the screw is located in the joint. Hence the head of the screw needs to be sunk in the CLT. Um das zu erreichen ist es notwendig, den Kopf der Schraube im CLT zu versenken. This means the screws need to penetrate the CLT $\frac{}{2\cdot\sqrt{2}}$ mm, measured from the center (vertical projected length), which equals to an actual screw length of:

$\sqrt{2}$

3.4.5.2 Characteristic point side withdrawal strength of the screw

$\frac{}{-}$

CLT Layer	Thickness (vertical)	Screw penetration (vertical)	Screw penetration (parallel to screw axis)	α	$F_{ax,\alpha,Rk}$
	[mm]	[mm]	[mm]	[°]	[N]
L1	40	22	31	45	2091
C12	20	20	28	90	2217
L2/1	10	10	14	45	950
Joint	0				
L2/2	10	10	14	45	950
C23	20	20	28	90	2217
L3	40	22	31	45	2091
			74		**5259**

3.4.5.3 Headside pull-through strength of the screw

Because the joint is located in the center of gravity of the screw, point side withdrawal is governing.

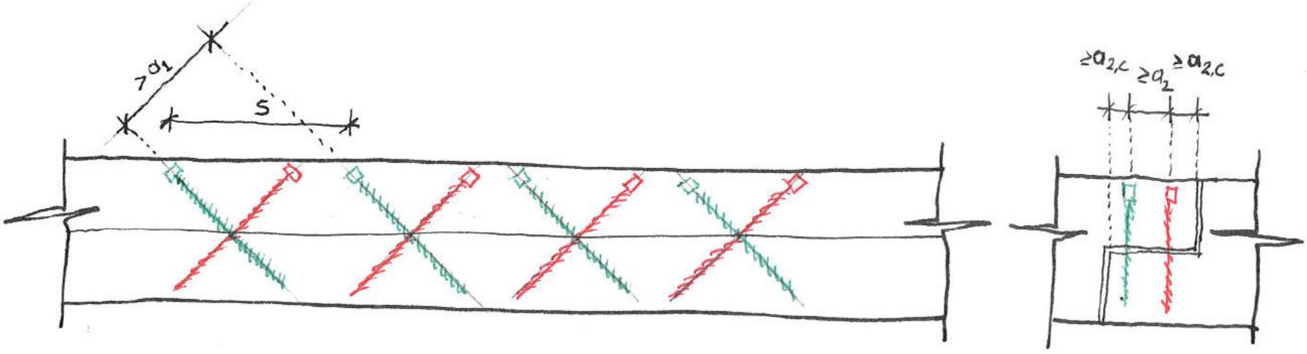
3.4.5.4 Tensile strength of the screw

$F_{t,u,k}$ = 9.100 N

Point side withdrawal of the screw is governing, accordingly: N.

CLT connections

3.4.5.5 Design withdrawal strength



3.4.6 Spacing and placement

2 rows Würth VG-screws (fully threaded), with a spacing of:

$$\sqrt{2} \qquad \sqrt{2}$$

3.4.7 Design shear capacity (maximum design shear capacity per linear meter)

$$\left(\frac{ax}{\sqrt{\ }} \quad \right) \qquad \left(\frac{\ }{\sqrt{2}}\right) \qquad \mathrm{N/lm}$$

ENGINEERED WOOD CONSTRUCTION
CLT-S

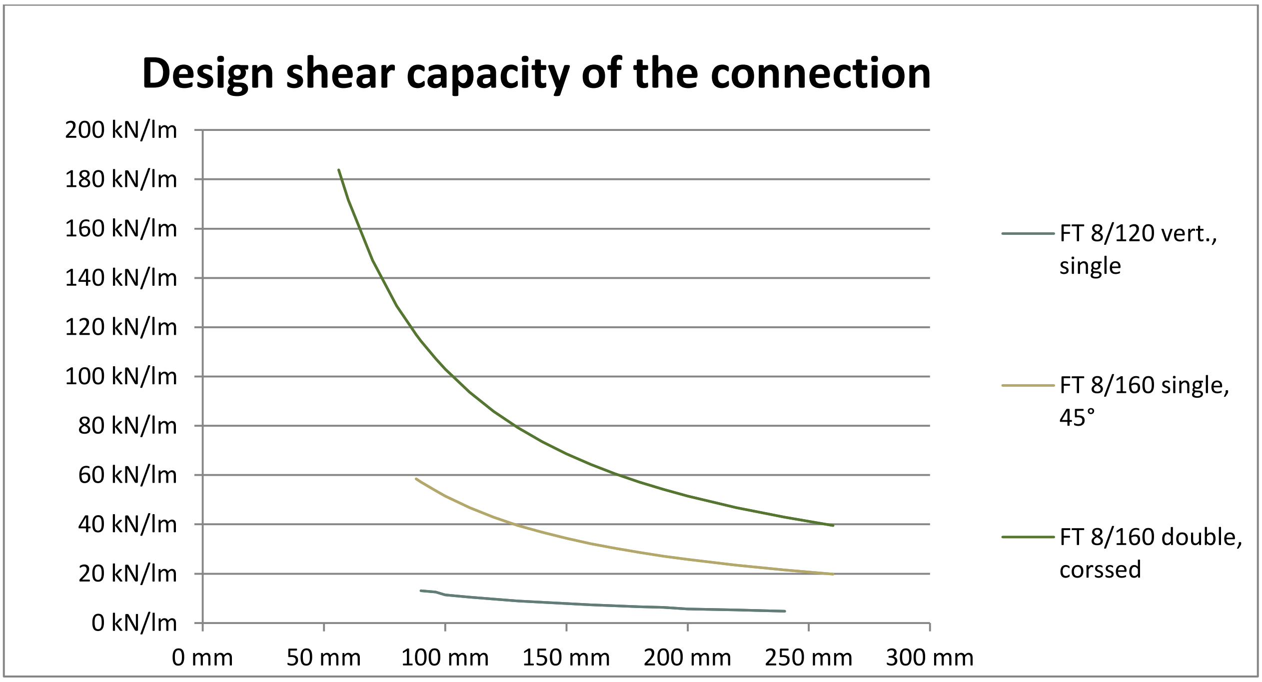
Lap splice

Screws Ø8/xxx

CLT spruce/pine (C24)

k_{mod} = 0,9

	Würth vertically	Würth 45° inclined, al-ternating	Würth 45° crossed
Spacing	Ø 8 / 120	Ø 8 / 160	Ø 8 / 160
s	$F_{v,RD}$	$F_{v,RD}$	$F_{v,RD}$
	[kN/lm]	[kN/lm]	[kN/lm]
56 mm			183,85
60 mm			171,59
70 mm			147,08
80 mm			128,69
88 mm		58,50	116,99
90 mm		57,20	114,39
96 mm	13,06	53,62	107,24
100 mm	12,54	51,48	102,95
110 mm	11,40	46,80	93,60
120 mm	10,45	42,90	85,80
130 mm	9,65	39,60	79,20
140 mm	8,96	36,77	73,54
150 mm	8,36	34,32	68,64
160 mm	7,84	32,17	64,35
170 mm	7,38	30,28	60,56
180 mm	6,97	28,60	57,20
190 mm	6,60	27,09	54,19
200 mm	6,27	25,74	51,48
220 mm	5,70	23,40	46,80
240 mm	5,23	21,45	42,90
260 mm	4,82	19,80	39,60



Design shear capacity of the connection
200 kN/lm
180 kN/lm
160 kN/lm
140 kN/lm
120 kN/lm
100 kN/lm
80 kN/lm
60 kN/lm
40 kN/lm
20 kN/lm
0 kN/lm
0 mm
50 mm
100 mm
150 mm
200 mm
250 mm
300 mm
FT 8/120 vert., single
FT 8/160 single, 45°
FT 8/160 double, corssed

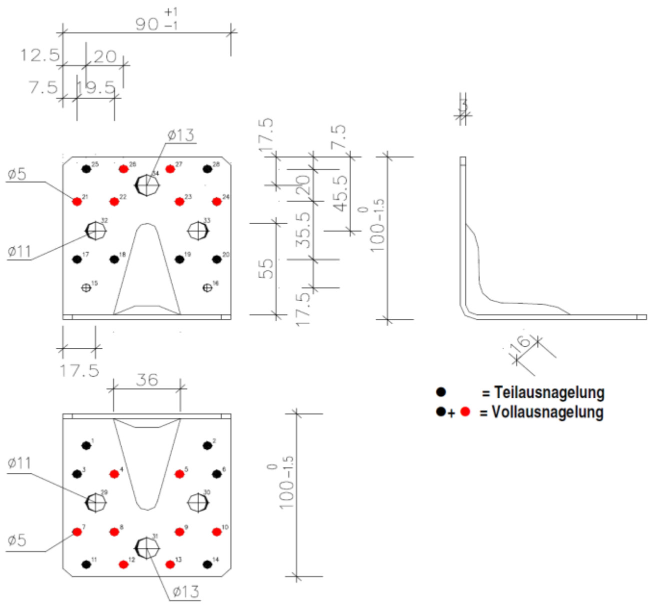
4 Butt joint with angle brackets

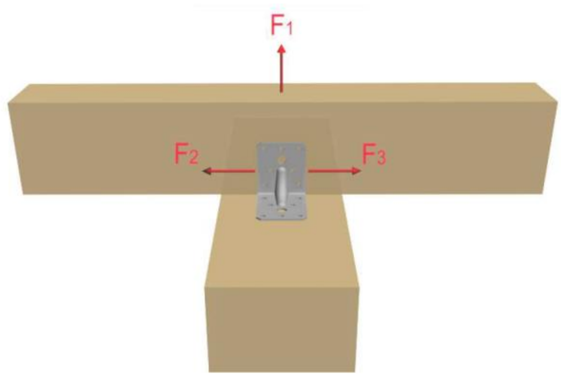
4.1 CLT:

Wood grade according to EN338: C24

ρ_k = 350 kg/m³

4.2 Angle bracket Rothoblaas WRB100:



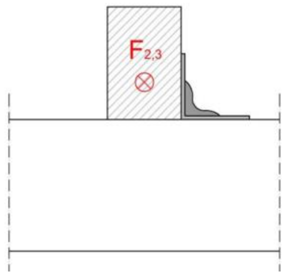


4.3 Connector:

- Anchor nails: 4,0x60 resistance class III according to EN14592
- Screws 5,0x60 according to Z-9.1-375 and EN 14592
- Anchorage to concrete: Hilti HSA (ETA-99/0001 2008-03-13)

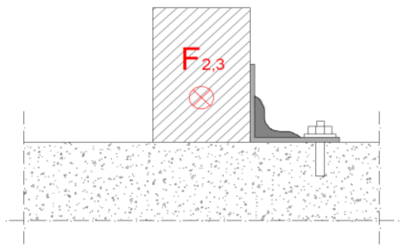
4.3.1 Shear capacity of angle brackets

Resistance R2/3 – 1 angle bracket per connection

Sketch	Angle bracket	$R_{2/3,k}$
	Full nailing $R_{2/3,k,tot}$	8,94 kN
	Partial nailing $R_{2/3,k,part}$	6,07 kN
	Fully screwed $R_{2/3,k,tot}$	11,72 kN
	Partially screwed $R_{2/3,k,part}$	7,81 kN
	When placing the angle brackets on both sides, the resistance will double.	

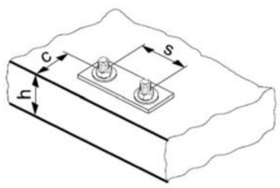
The angle brackets shown above are also capable of resisting uplift forces in direction F_1. Stora Enso Wood Products GmbH suggests to introduce uplift forces in CLT panels with special hold-down connectors, designed for that purpose. If uplift forces shall still be considered, please proceed according to ETA-09/0323.

4.3.2 Anchorage to concrete



The Angle bracket WBR100 can be anchored to concrete as well. According to ETA-09/0323, the same shear forces can be transferred as from wood to wood.

Anchorage to concrete with Hilti HSA M12:

Design values for Hilti HSA M12		
V_{Rd}	23,8 kN	
t_{min}	100 mm	
s_{min}	270 mm	
c_{min}	135 mm	
Min. concrete grade	C20/25	

Due to the high resistance of the anchorage of an angle bracket to a concrete base, the anchorage resistance to concrete will not govern the connection design.