UNIVERSITY OF ALBERTA

CANADIAN WOOD CONSTRUCTION RESEARCH NETWORK

NSERC Alliance Grant Project 'NEXT-GENERATION WOOD CONSTRUCTION'

A CWCRN Initiative

Rolling shear and punching shear of CLT

Houman Ganjali
Ph.D. Candidate

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

Dr. Thomas Tannert
Supervisor

Dr. Jianhui Zhou
Supervisory committee member

Dr. Md Shahnewaz
Supervisory committee member
Industry partner

Carla Dickof
Industry partner

Dr. Marjan Popovski
Supervisory committee member

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Point Supported CLT (Post+Plank)

Muster M. and Frangi A. 2020

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Punching shear in CLT

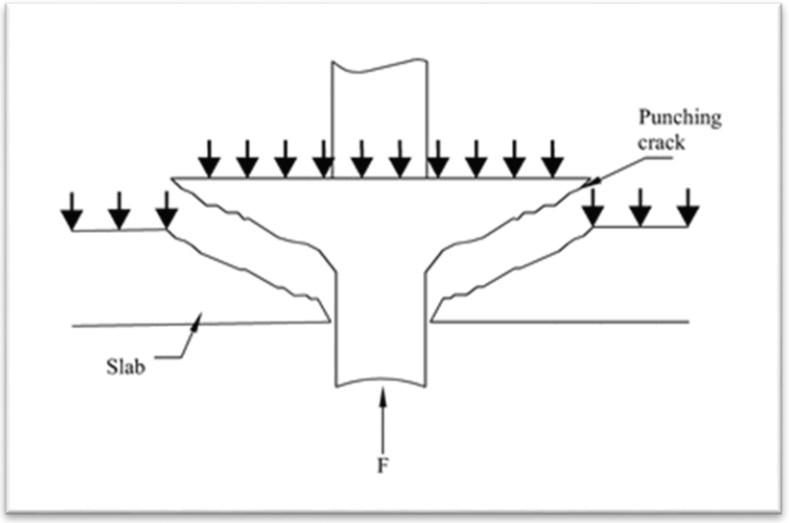
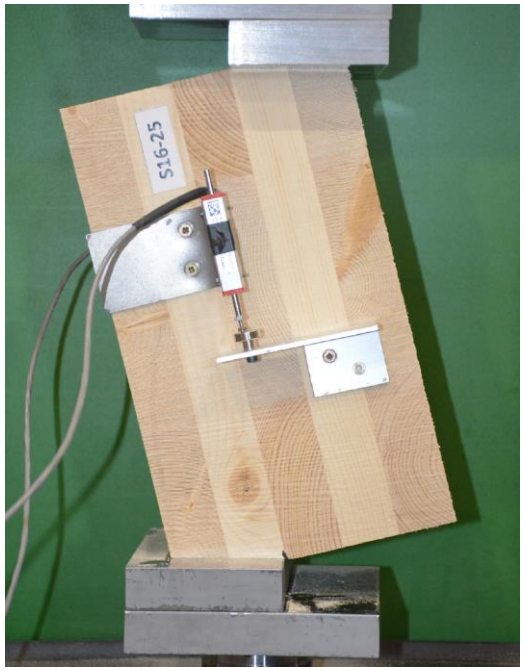


Photo credit: Dr. Thomas Tannert

Rolling shear inclined tests

- 689 specimens
- 22 series
- 5 CLT providers
- E1 & V2 stress grades
- 3- & 5-layered layups
- 4 species (Spruce, SPF, HEM, D-Fir)
- Minor and major direction
- 2 test layer thicknesses
- Edge glued and non-edge glued

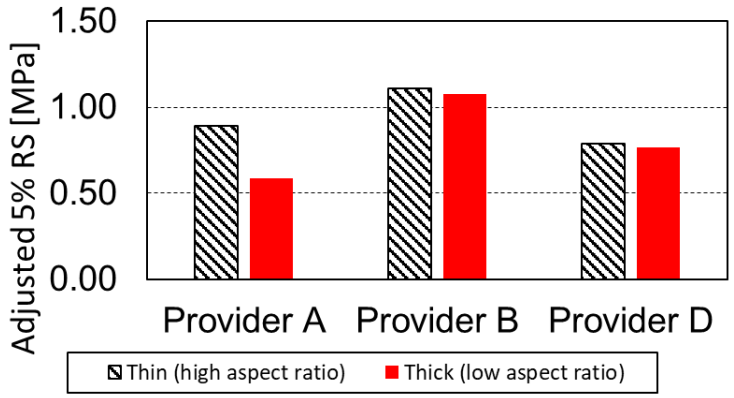


Series	5th% [MPa]	ADJ [MPa]
S1	1.02	0.89
S2	0.62	0.54
S3	0.73	0.64
S4	1.27	1.11
S5	1.24	1.08
S6	1.24	1.08
S7	0.84	0.73
S8	0.74	0.64
S9	0.74	0.64
S10	1.10	0.96
S11	0.71	0.61
S12	0.82	0.71
S13	1.08	0.94
S14	0.70	0.61
S15	0.88	0.77
S16	0.88	0.77
S17	0.87	0.76
S18	0.84	0.73
S19	0.88	0.77
S20	0.90	0.78
S21	1.14	0.99
S22	0.92	0.80

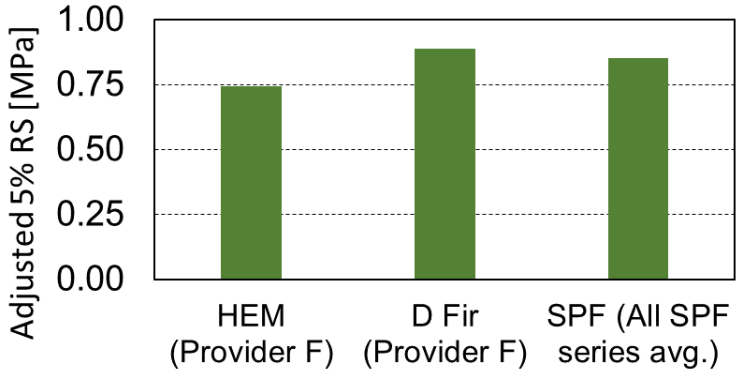
CSA O86 RS value: 0.5-0.6 MPa

Rolling shear inclined test results

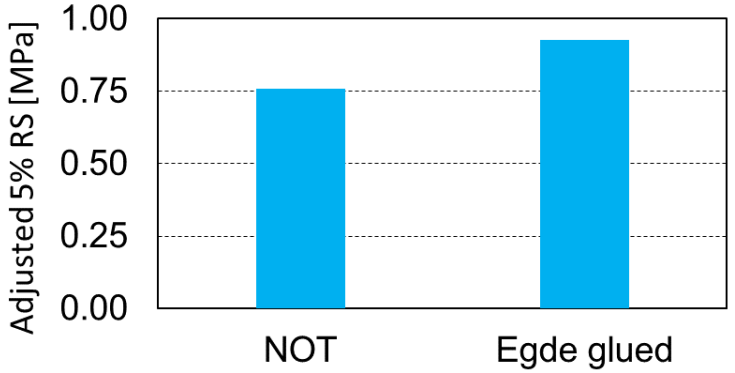
-CLT provider
-Board width to thickness ratio



Timber species



Edge gluing



Four- & three-point bending tests

48 Specimens 1.7 m x 0.3 m

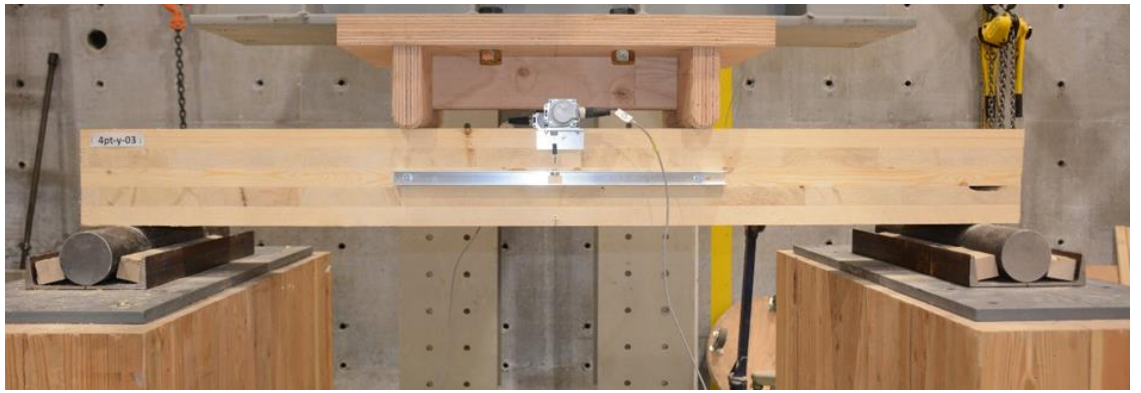
- E1 stress grade, 5-layered CLT
- Major and Minor

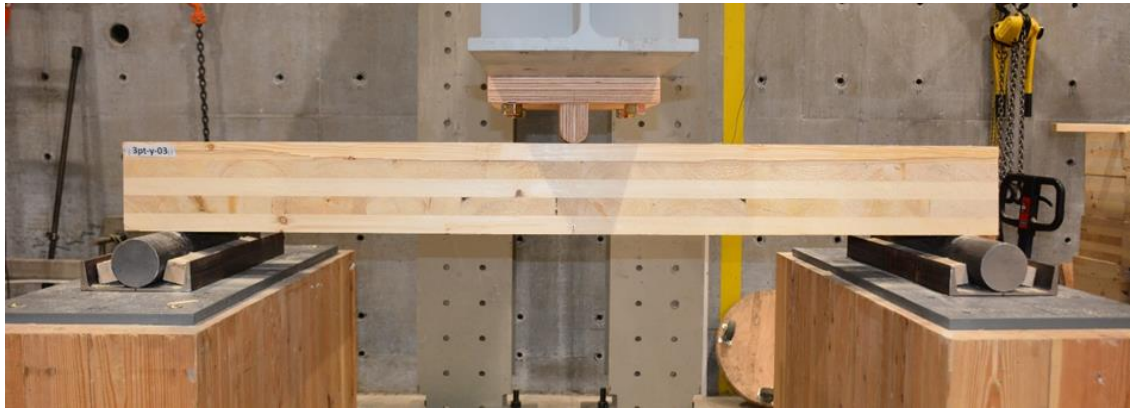
Series	Mean [MPa]	5th% [MPa]	ADJ [MPa]
3pt-y	1.10	0.98	0.85
3pt-i	1.28	0.98	0.85
4pt-y	1.47	1.20	1.04
4pt-i	1.29	1.10	0.96

> 0.5-0.6 MPa

Mean RS strength from modified inclined test

Major	1.62 MPa
Minor	1.14 MPa





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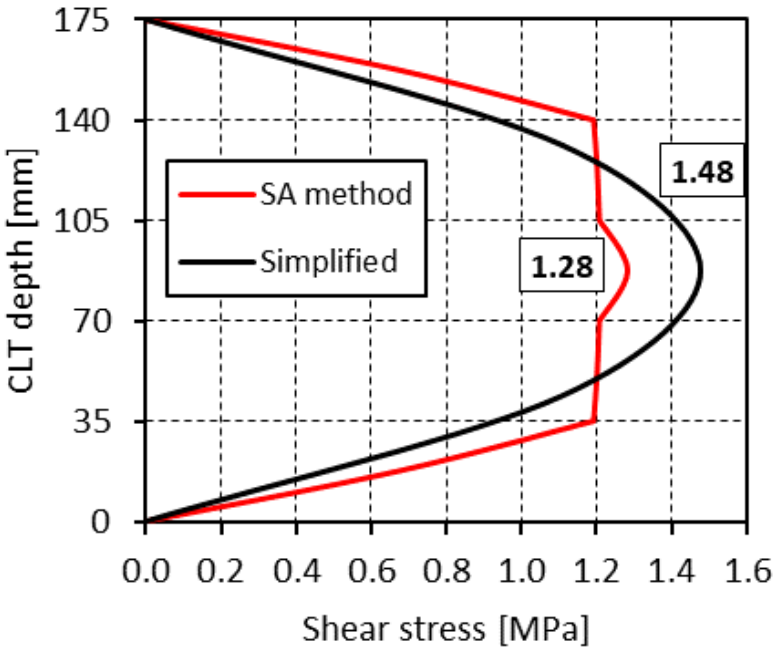
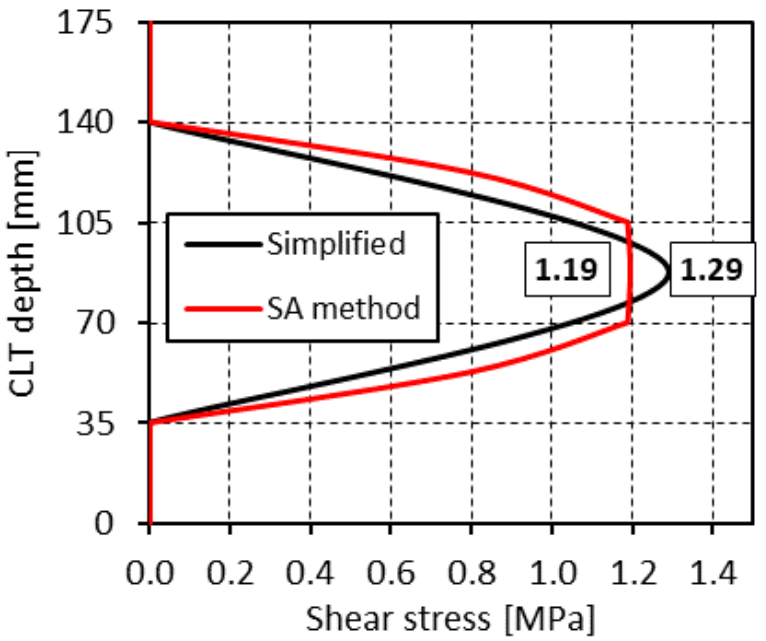
Four- & three-point bending tests

-Simplified method

$$f_s = \frac{1.5 \times F}{t_{\mathrm{CLT}} \times width}$$

-Shear analogy (SA) method

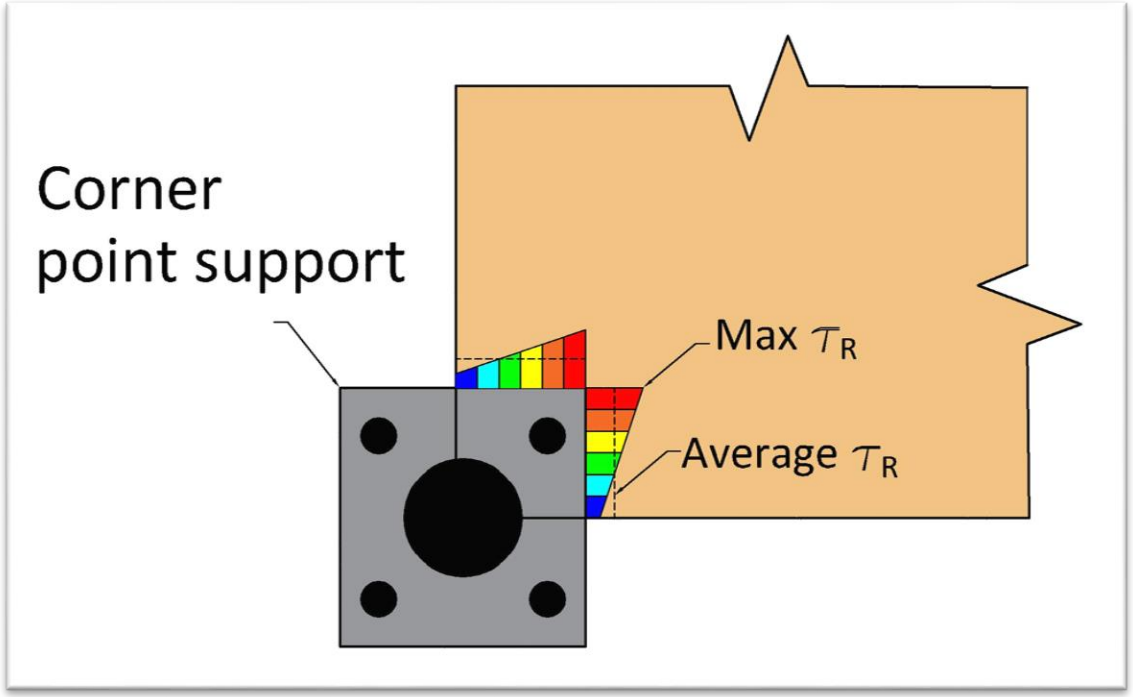




Rolling shear stresses based on simplified and SA methods: major (left); minor(right)

Punching shear tests

- Influencing parameters on the punching shear capacity of CLT



Punching shear test overview

32 series (so far)

4 providers

2 grades

2 thicknesses

3 species

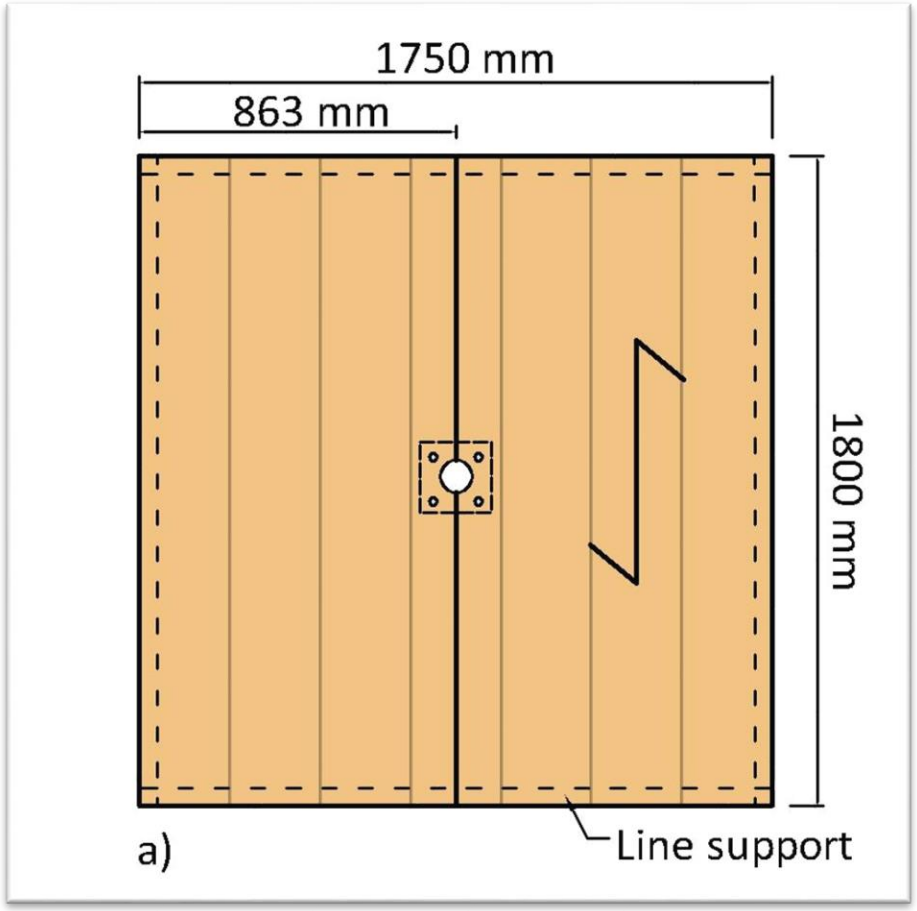
3 support geometries

4 column conditions

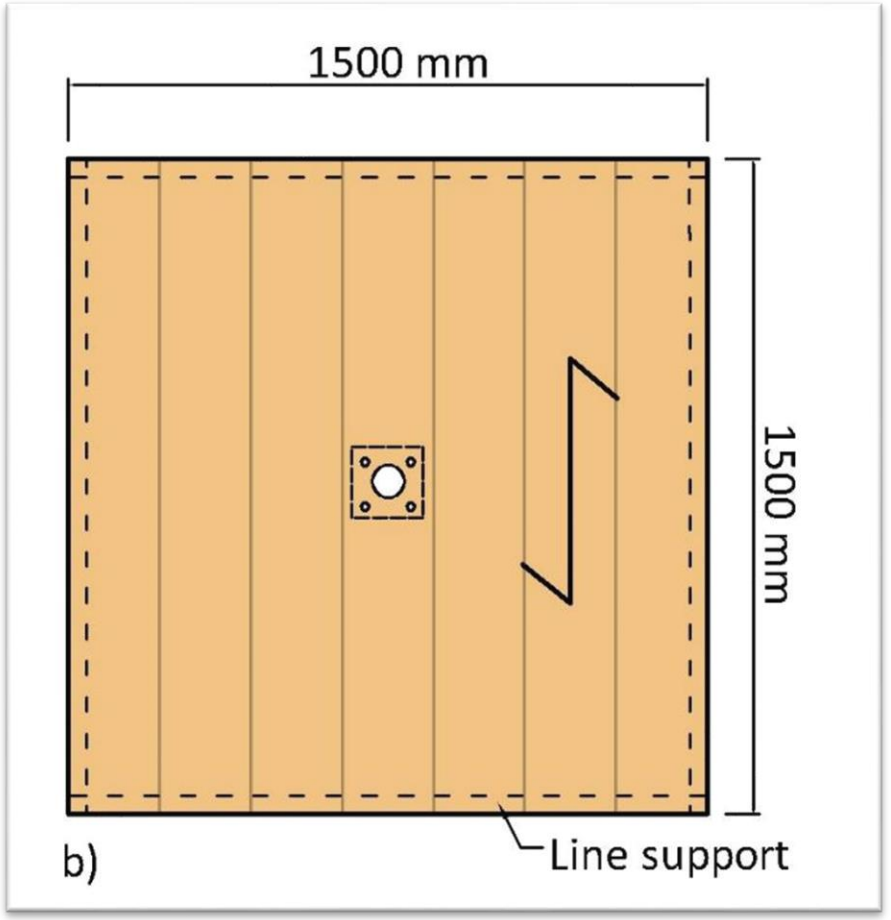
STS reinforcements

Series	Producer	Grade	Thickness [mm]	Species	Support [mm x mm]	Support	Reinforcem.
S1	D	V2	175	SPF	200 x 200	Edge	None
S2	D	E1	175	SPF	200 x 200	Edge	None
S3	A	E1	175	Spruce	200 x 200	Edge	None
S4	B	E1	175	SPF	200 x 200	Edge	None
S5	B	E1	175	SPF	300 x 300	Edge	None
S6	F	V2	175	SPF	200 x 200	Edge	None
S7	F	E1	175	SPF	200 x 200	Edge	None
S8	F	E1	175	D Fir	200 x 200	Edge	None
S9	F	E1	175	HML	200 x 200	Edge	None
S10	F	E1	175	SPF	460 x 180 LLP	Edge	None
S11	F	E1	175	SPF	460 x 180 SLP	Edge	None
S12	F	E1	175	SPF	Ø 219	Edge	None
S13	F	E1	175	SPF	200 x 200, 10^{+}	Edge	None
S14	F	E1	175	SPF	200 x 200, 25^{+}	Edge	None
S15	F	E1	175	SPF	300 x 300	Edge	None
S16	F	E1	175	SPF	200 x 200*	Edge	None
S17	F	E1	245	SPF	300 x 300	Edge	None
S18	F	E1	175	SPF	200 x 200	Edge	STS
S19	F	E1	175	SPF	200 x 200	Edge	STS
S20	F	E1	175	SPF	200 x 200	Edge	STS
S21	F	E1	175	SPF	400 x 400	Edge	STS
S22	F	E1	175	SPF	200 x 200	Edge	STS
S23	F	E1	175	SPF	200 x 200**	Edge	None
S24	F	E1	175	SPF	200 x 200	Interior	None
S25	F	E1	175	SPF	Ø 219	Interior	None
S26	F	E1	175	SPF	200 x 200	Interior	None
S27	F	E1	175	SPF	200 x 200	Interior	None
S28	F	E1	175	SPF	200 x 200	Interior	None
S29	F	E1	245	SPF	300 x 300	Interior	None
S30	F	E1	175	SPF	200 x 200	Perimeter	None
S41	F	E1	175	SPF	200 x 200	Corner	None
S42	F	E1	245	SPF	200 x 200	Corner	None

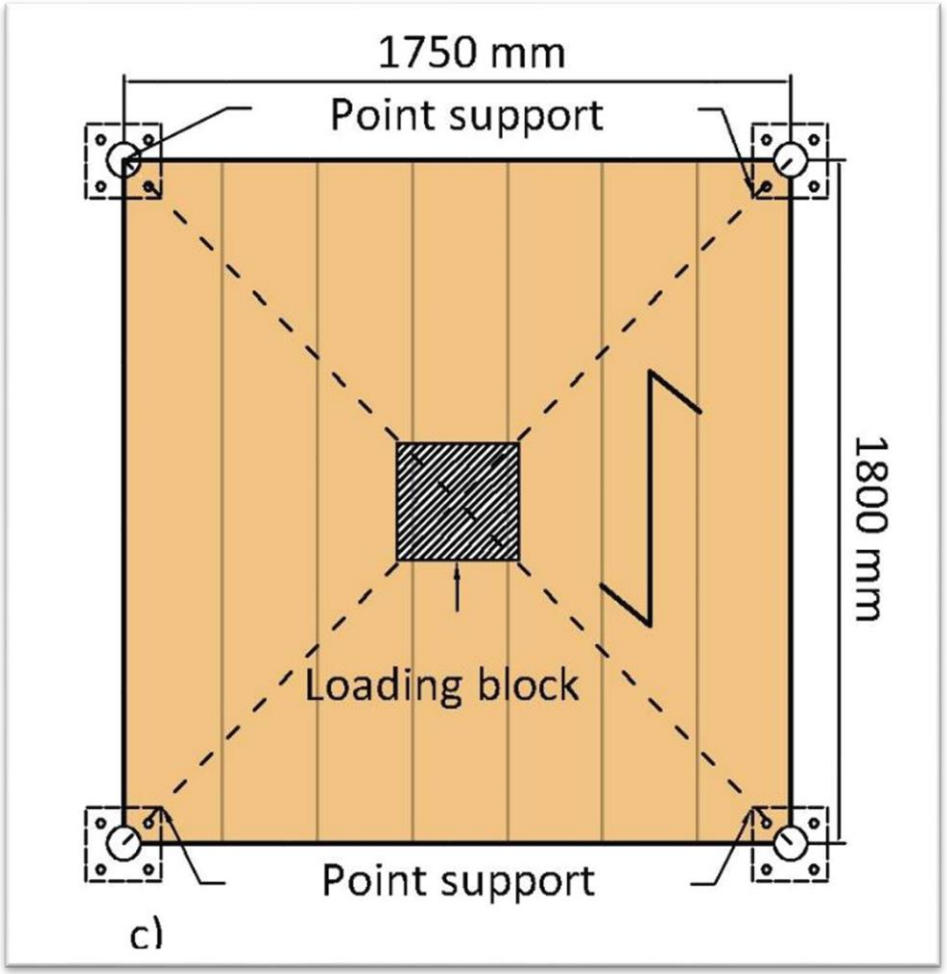
- Edge support



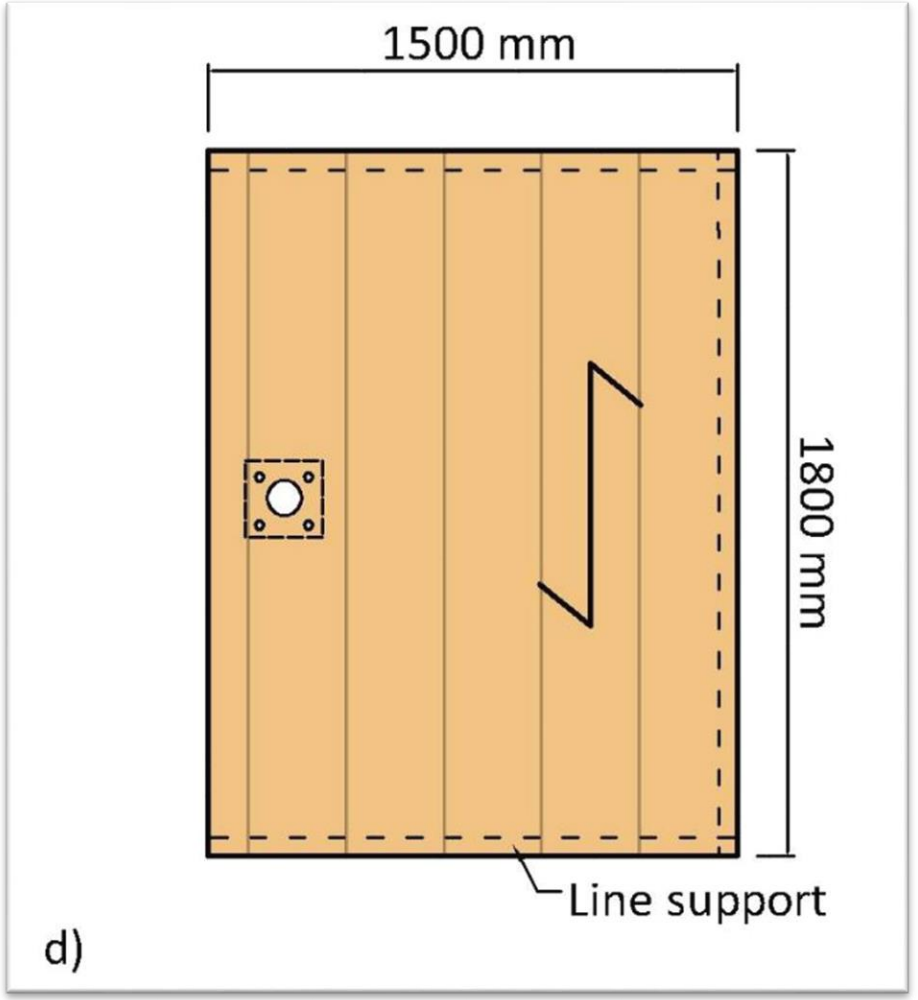
- Centre support



- Corner support



- Perimeter support



Column geometry

- Square plate + wooden stub

  200×200 mm

  300×300 mm

Column geometry

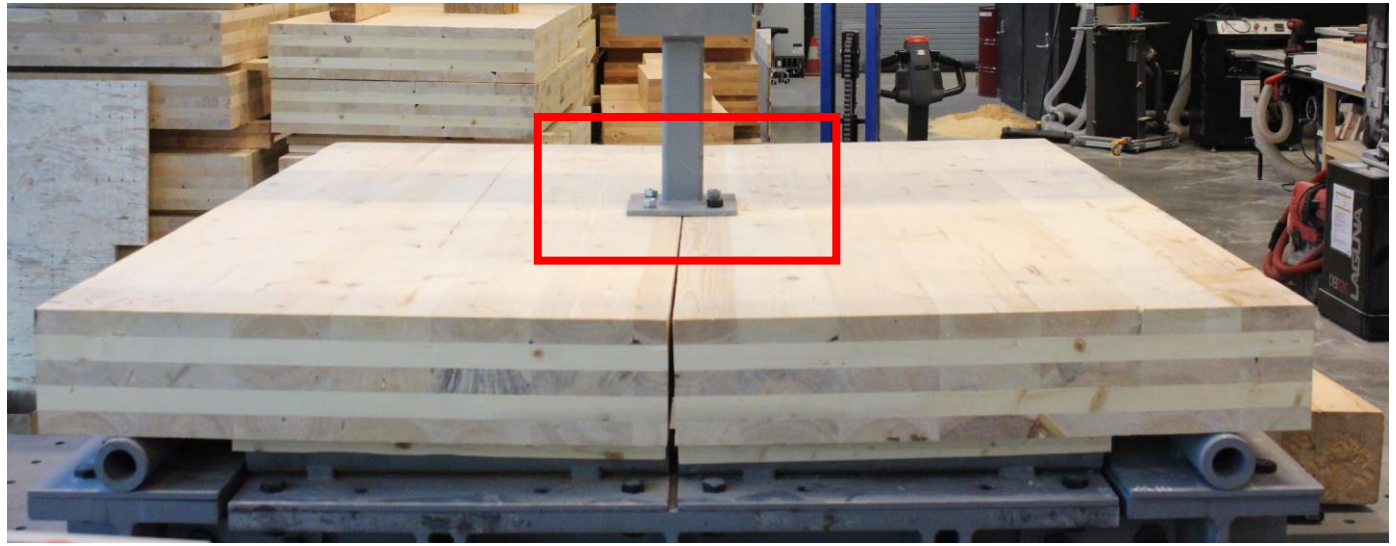
- Rectangular + wooden stub
- X- and Y-oriented

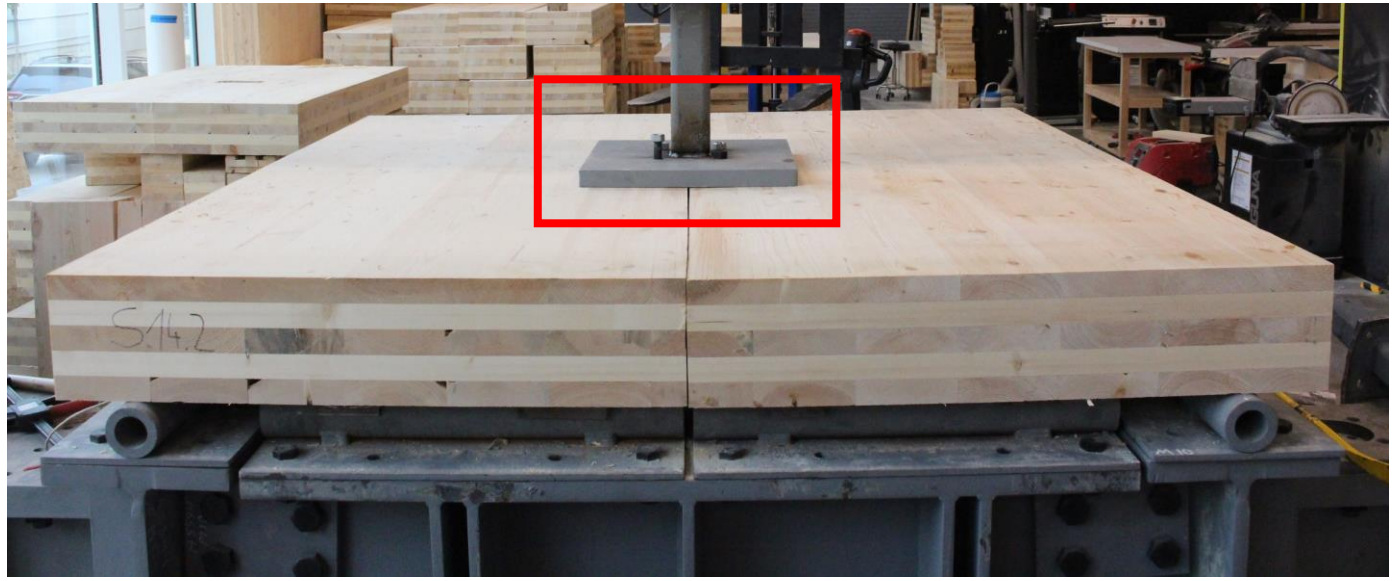
Column geometry

- Round + stub

Column geometry

- Square plate & NO stub
- 200×200 mm, low out of plane stiffness
- 400×400 mm, high out of plane stiffness





Screw reinforcement design (@45°)

Equivalent RS strength [MPa] = RS strength of wood + Screw contribution to RS

$$\text{Screw contribution to RS} = \frac{R_{ax,k} \times \sqrt{2}}{a_1 \times a_{2,eff}}$$

$R_{ax,k}$ = screw withdrawal strength

a_1 = distance between screws

$a_{2,eff}$= distance between screw rows

Reinforcement zone length?

Reinforcement direction?

5 series

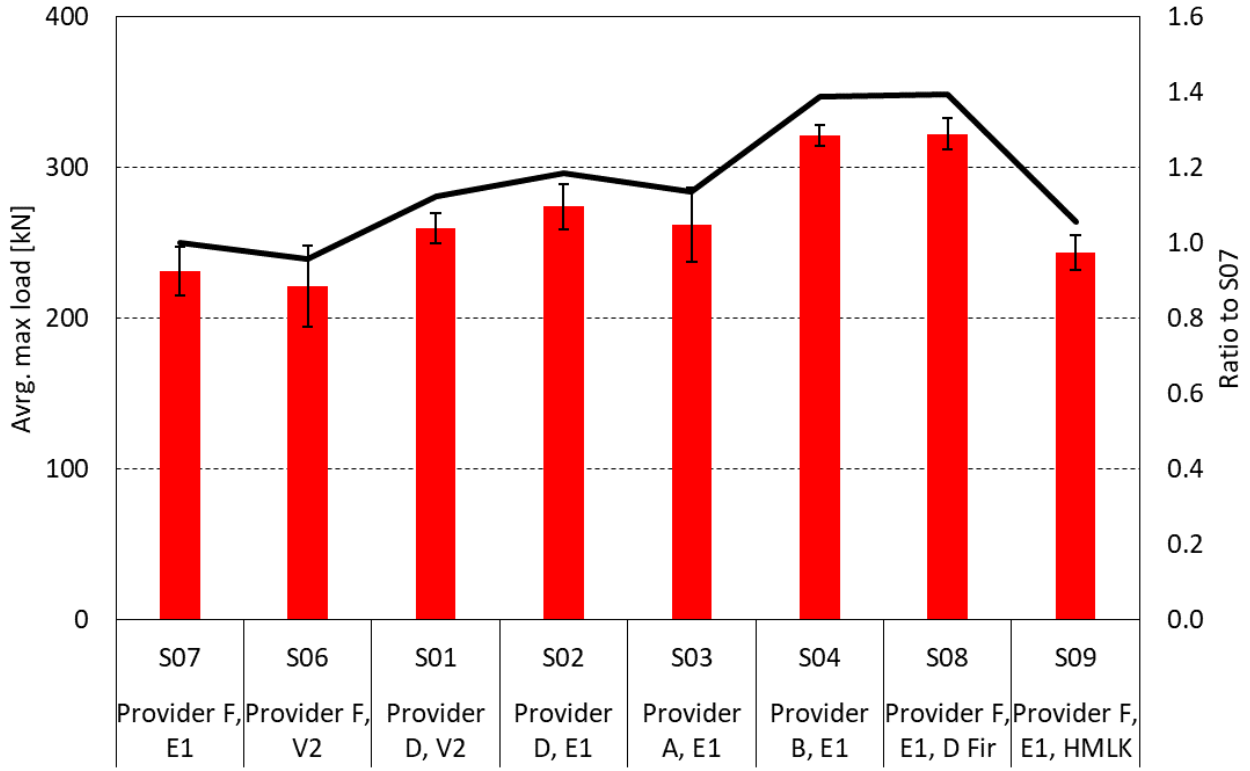
Only **2** estimates: 42% and 27%

CLT punching shear results

Provider B CLT had the highest capacity

D Fir and Hemlock were stronger

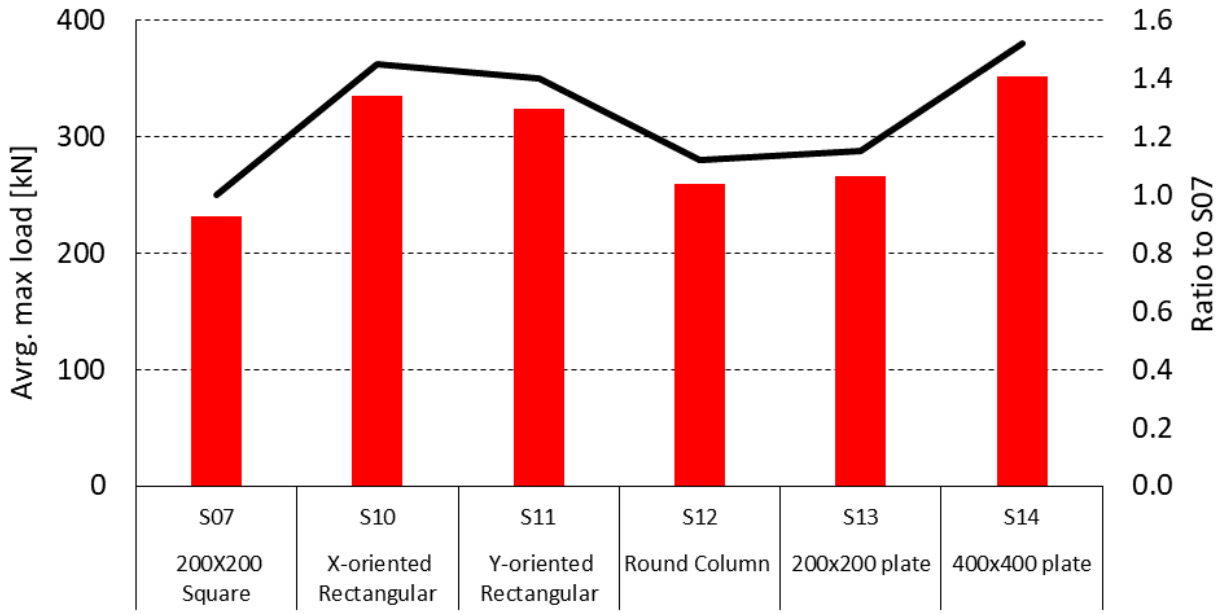
E rated series were slightly stronger



CLT punching shear results

- Round geometry
= less stress concentration

- Softer loading plate
= higher capacity



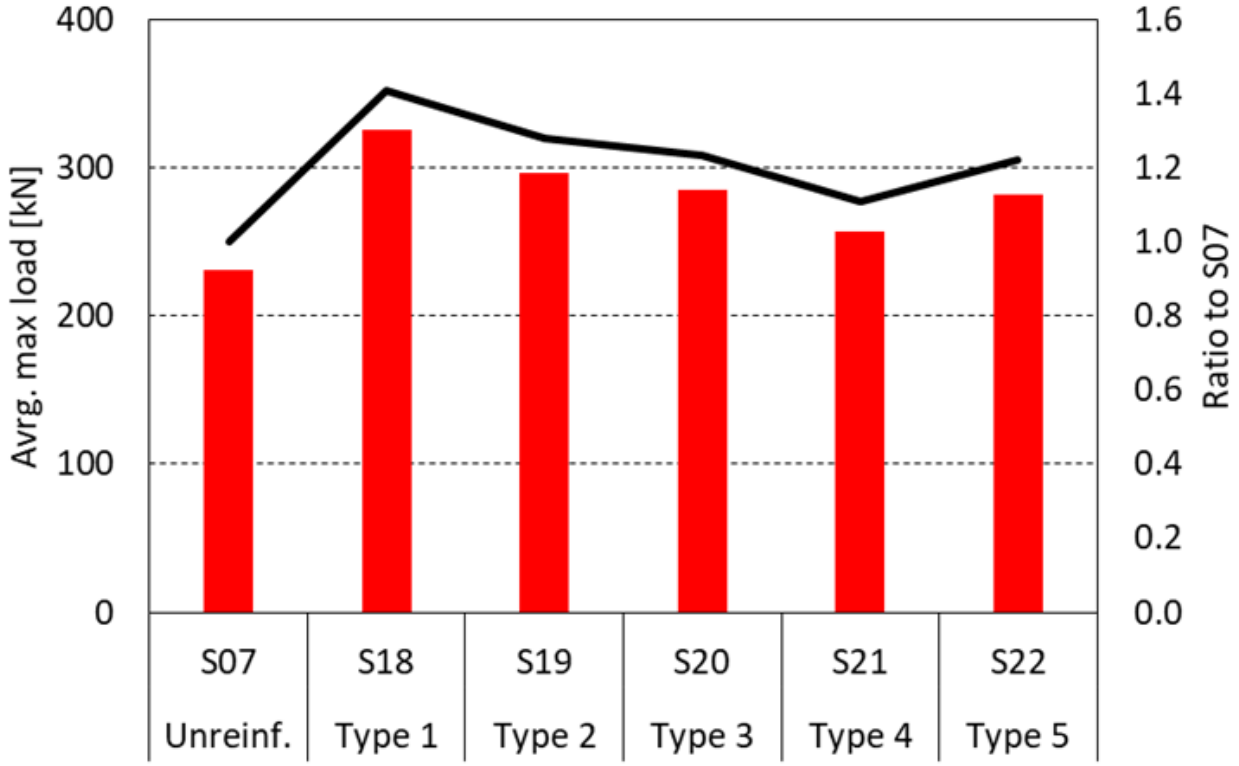
CLT punching shear results

Highest increase 41%:

- Largest reinf. zone
- Both directions
- Tight screw spacing

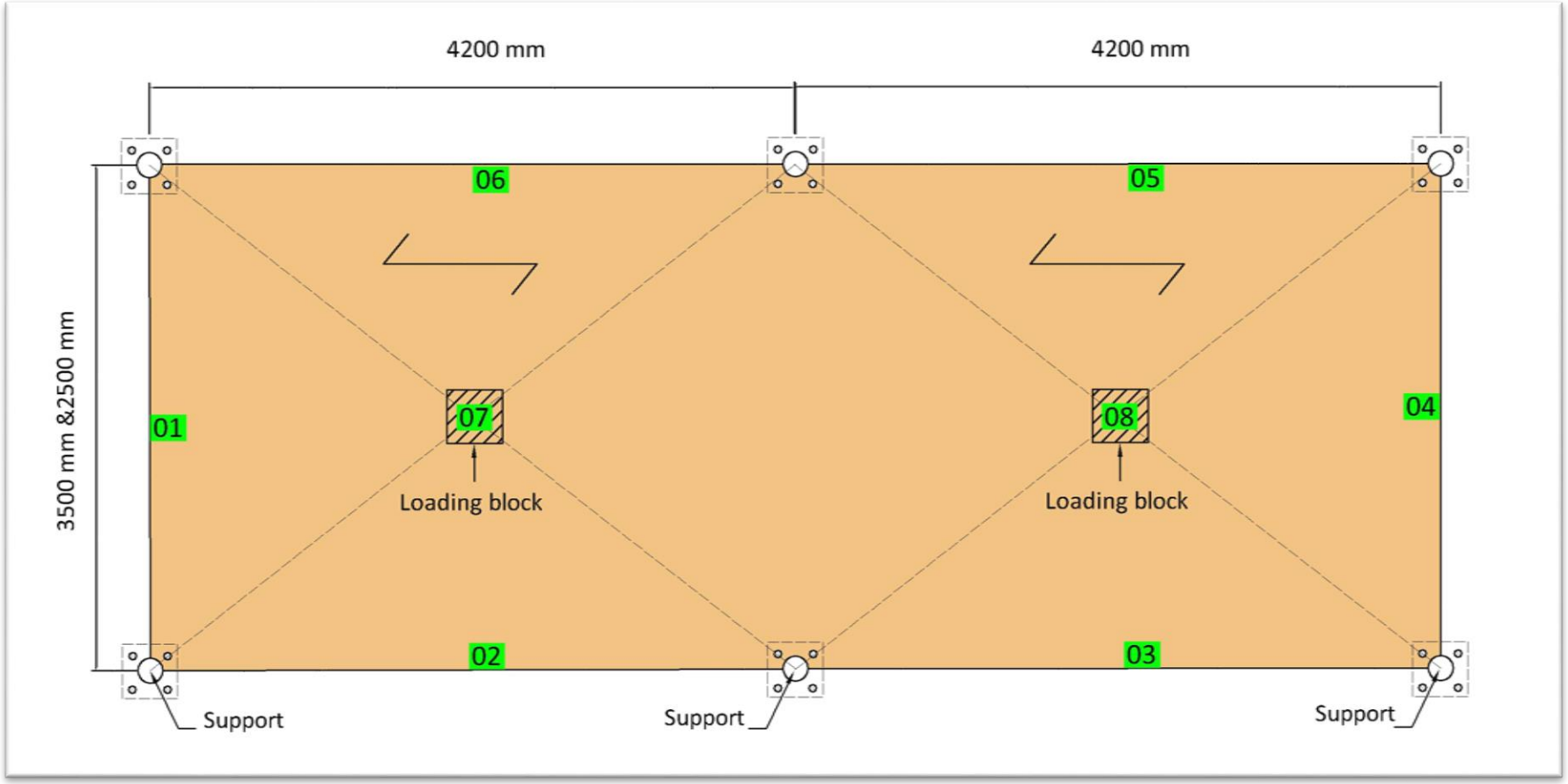
Important factors:

- Reinf. level
- Reinf. zone
- Reinf. direction



Project outlook

- Full-scale floor tests



Project outlook

- Design guidance for point-supported CLT floors punching shear

1. Stress distribution model

2. Adjustment factors
   - Material related
   - Support condition related