Punktgestützte Decken aus Brettsperrholzplatten

Point-supported CLT floors

Thomas Tannert
UNBC
Prince George, Kanada
thomas.tannert@unbc.ca

Houman Ganjali
UNBC
Prince George, Kanada
ganjali@unbc.ca

Carla Dickof
Fast + Epp
Vancouver, Kanada
cdickof@fastepp.com

Md Shahnewaz
Fast + Epp
Vancouver Kanada
mshahnewaz@fastepp.com

Thomas Tannert
Thomas Tannert
University of Northern British Columbia
xvxdvdvzdvPrince George, Kanada
University of Northern British Columbia
Prince George, Kanada
thomas.tannert@unbc.ca

Point-supported CLT floors

1. Introduction

In recent years, cross-laminated timber (CLT) has been increasingly used as a sustainable alternative to conventional construction materials, particularly for floor applications [1]. This includes point-supported flat-slabs, also called post+plank, such as in the 18-storey Tall Wood House in Vancouver [2], shown in Figure 1a. The crosswise orientation of CLT layers and its inherent mechanical properties are better utilized when adopted as point-supported flat-slabs. In this system, the CLT panels are sup-ported directly by columns, without the need for beams and their connections, reducing installation cost and time, allowing the layout to be readily changed by altering wall locations, and increasing the free floor height [3].

One relevant material strength property in these applications is the CLT punching shear strength, which refers to its ability to resist concentrated loads or "punching" through the material, as illustrated in Figure 1b. CLT punching shear strength is directly related to the lamella rolling shear strength [4], which can be estimated through 4-point bending, 3-point bending, or inclined in-plane shear tests. Previous research has shown that CLT rolling shear strength increases under punching shear due to the confinement effect of lamellas from adjacent layers (clamping effect) and the presence of compression forces perpendicular to grain [5-7].

a)

b)

Figure 1: Point-supported CLT floor: a) UBC Tall-Wood house, photo credit: Fast+Epp; b) Punching shear failure, photo credit: Thomas Tannert

2. Experimental investigations

2.1. Objectives

The current North American and European do not provide any direct guidance on the design of point-supported CLT floors. To address this need, a project is being conducted in collaboration between Fast + Epp, Concept Lab and the University of Northern British Columbia with the objective to develop design guidance for point supported CLT floors. To achieve this objective, an experimental punching shear testing program is underway.

2.2. Investigated support conditions

Following parameters, as illustrated in Figure 2 are investigated: i) point support location (columns at the panel center, edge, and corner, Figure 3; ii) CLT lamella species, grade (E1 and V2 graded SPF, Douglas Fir, and Hemlock CLT panels), and layup; iii) column geometry and size (square, rectangle, round), see Figure 4; and iv) level and type of reinforcement. A total of 32 punching shear test series consisting of six replicates are planned with CLT specimens sized 1.7·1.8 m, 1.5·1.8 m, and 1.5·1.5 m. To date, 21 series with interior edge-column, two series with interior panel corners, and four series with the CLT panels reinforced with self-tapping screws have been tested.

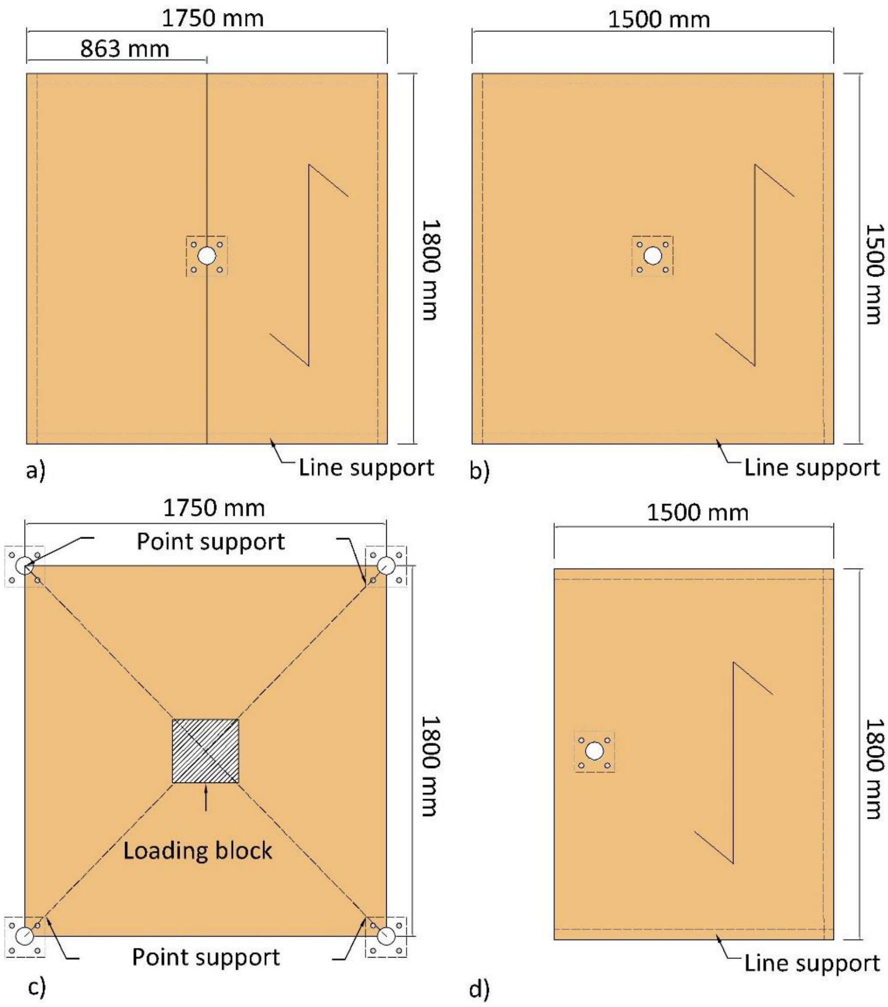

Figure 2: Punching shear support locations: a) interior edge-column; b) interior mid-panel; c) interior panel corner; d) building perimeter

A steel column stub connection was used to keep the half panels connected in the interior edge-column conditions. This steel stub had four steel unthreaded rods and a washer plate on the bottom face of the panels. One series was tested with the steel column stub, but the unthreaded rods were substituted by 4 1/2·6" lag bolts (S16); one series was tested having just the hole required for the steel column stub and using 4 #10·4" wood screws (S23), and one series was tested without any hole or steel column stub in the middle but reinforced with 4 1/2·6" lag bolts (S15). The interior edge condition specimens were line-supported on four edges along the length, while the interior panel corner condition specimens were point-supported on four corners having the same bearing area, ensuring an equal possibility of failure for all corners. Selected examples are shown in Figure 3.

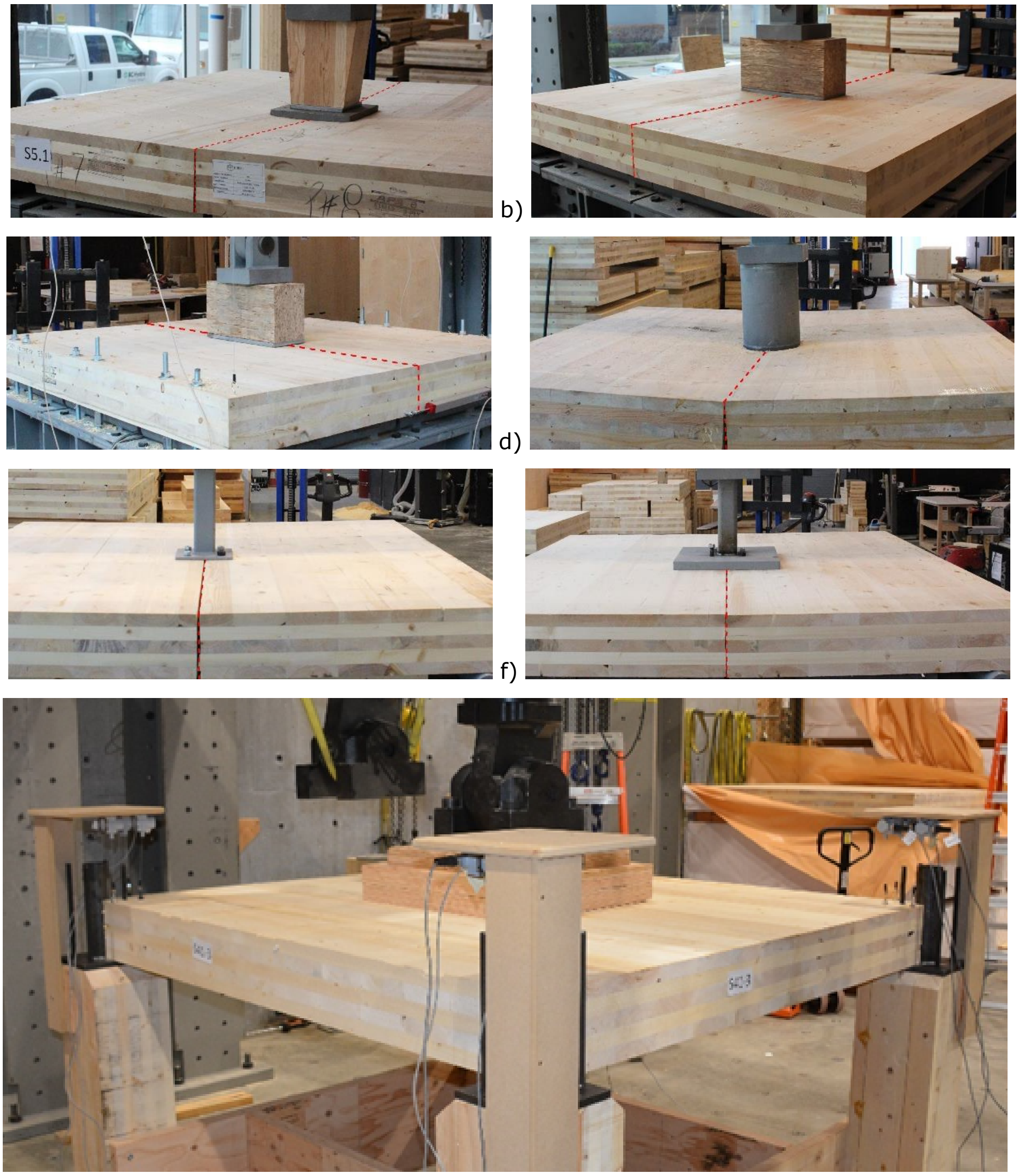

Figure 3: Different column configurations: a) square plate with wood column; b) Minor direction oriented rectangular plate with wood column (S10); c) major direction oriented rectangular plate with wood column (S11); d) round column (S12); e) 200·200 mm square plate and HSS (S13); and f) 400x400 mm square plate and HSS (S14).; f) typical interior panel corner condition setup.

The reinforced series in this study were designed based on the model proposed by Mestek and Dietsch [8]. The model is a function of the load carrying capacity of a screw parallel to its axis and the distance between the screws and screw rows. However, the length of the self-tapping screw reinforcement zone and the effect of reinforcement direction are yet to be determined. To date, five series with self-tapping screws as shear reinforcement in an interior edge column condition have been tested. Those series were designed in such a way to evaluate the effectiveness of STS shear reinforcement for point-supported CLT floor, the effect of the distance between screws and between each individual row of screws, the effect of having screw reinforcement in both directions and the length of reinforced zone. The reinforced series illustrated in Figure 4.

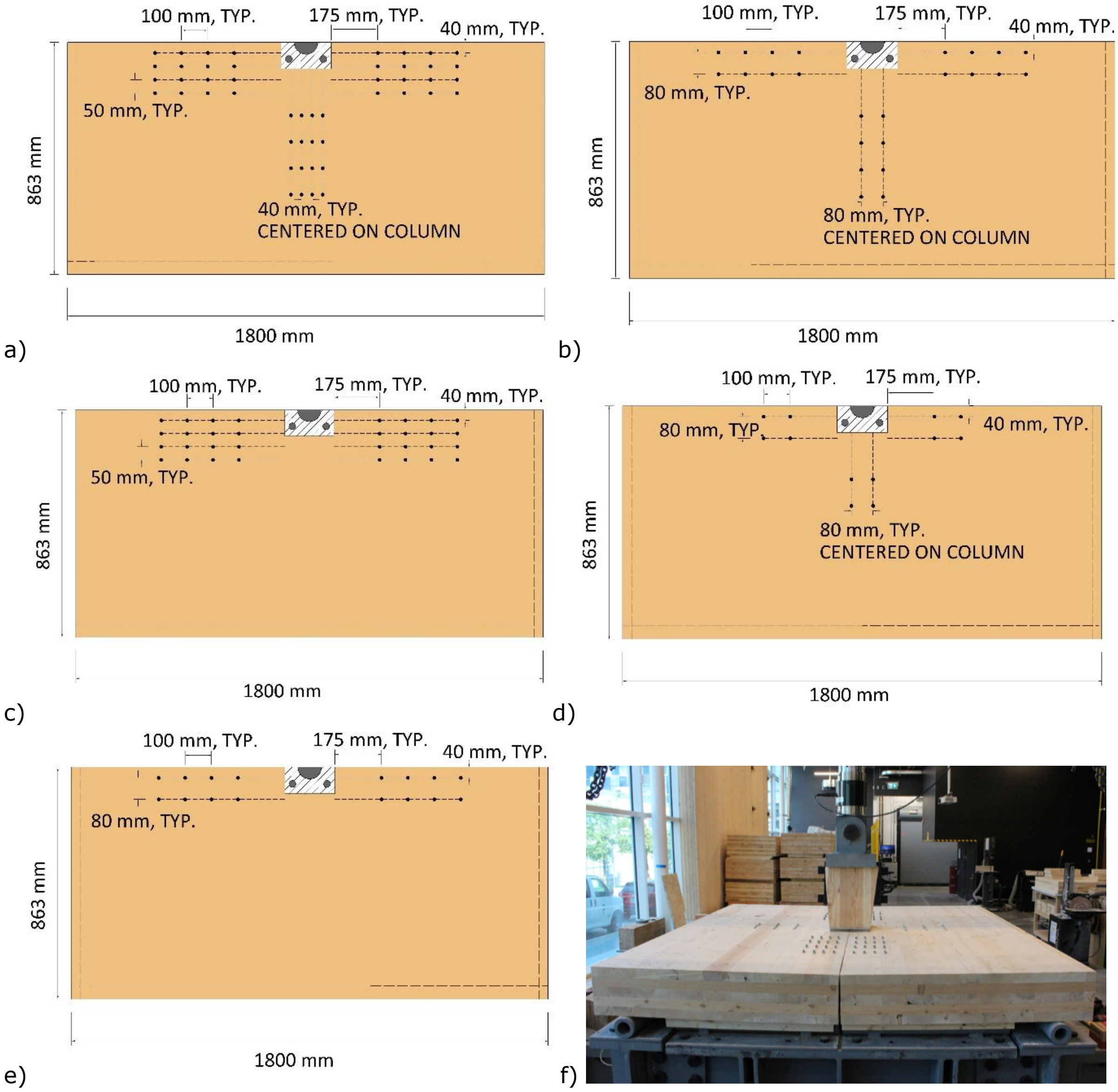

Figure 4: Screw shear reinforced series: a) type 1 (S18); b) type 2 (S19); c) type 3 (S20); d) type 4 (S21); e) type 5 (S22); and f) type 1 series exemplary photo.

2.3. Results

The results to date are presented in Table 1.

Table 1: test results to date

ID	Prod.	Grade	Species	F_{max} [kN]	COV [%]	*Condition*	Column shape	Size [mm]	Thick. [mm]
S01	D	V2	SPF	259.8	3.9	Int. edge	Square	200x200	175
S02	D	E1	SPF	273.9	5.5	Int. edge	Square	200x200	175
S03	A	E1	Spruce	262.3	9.4	Int. edge	Square	200x200	175
S04	B	E1	SPF	321.1	2.1	Int. edge	Square	200x200	175
S05	B	E1	SPF	347.6	2.2	Int. edge	Square	300x300	175
S06	F	V2	SPF	221.2	12.3	Int. edge	Square	200x200	175
S07	F	E1	SPF	231.2	6.8	Int. edge	Square	200x200	175
S08	F	E1	D Fir	322.2	3.2	Int. edge	Square	200x200	175
S09	F	E1	HML	243.7	4.8	Int. edge	Square	200x200	175
S10	F	E1	SPF	335.0	3.9	Int. edge	Rectangular	180x458	175
S11	F	E1	SPF	324.0	3.9	Int. edge	Rectangular	180x458	175
S12	F	E1	SPF	259.4	5.0	Int. edge	Round	Ø220	175
S13	F	E1	SPF	265.8	5.1	Int. edge	Square	200x200	175
S14	F	E1	SPF	333.0	14.3	Int. edge	Square	400x400	175
S15	F	E1	SPF	209.2	6.1	Int. edge	Square	200x200	175
S16	F	E1	SPF	259.2	3.6	Int. edge	Square	200x200	175
S18	F	E1	SPF	325.6	9.5	Int. edge	Square	200x200	175
S19	F	E1	SPF	296.0	5.1	Int. edge	Square	200x200	175
S20	F	E1	SPF	284.6	4.4	Int. edge	Square	200x200	175
S21	F	E1	SPF	256.3	5.2	Int. edge	Square	200x200	175
S22	F	E1	SPF	281.9	6.9	Int. edge	Square	200x200	175
S23	F	E1	SPF	217.8	7.5	Int. edge	Square	200x200	175
S41	F	E1	SPF	255.0	5.6	Corner	Square	200x200	175
S42	F	E1	SPF	387.8	8.9	Corner	Square	200x200	245

The punching shear strength of CLT panels with an interior edge column condition as function of CLT manufacturer, wood species, and stress grade is illustrated in Figure 5. Among the 175 mm SPF series, S04 from manufacturer B had the highest strength, with its average being 40% larger than that of S07. This indicates that panels from different CLT manufacturers but having the same stress grade and species have different punching shear strength. With regard to timber species, the Douglas Fir series (S08) outperformed most SPF series; using this species increased the punching shear strength of the panels by 40% when compared to the SPF series of the same manufacturer. This increase was 10% when Hemlock panels were used (compare S09 and S07).

The effect of different column shapes on the load-carrying capacity of CLT panels is shown in Figure 6. A 45% and 40% increase was attained when X- and Y-oriented rectangular columns (Figure 3b and c) were used. The stiffness of the load distribution plate affects the punching shear strength. In S07, a 200 mm × 200 mm load distribution plate with a wooden column was used (similar to Figure 3d), while in S13, only a load distribution plate of the same size was used (Figure 3e). Based on the results, the softer load distribution plate used in S13 resulted in 13% in punching shear strength. Comparing the S14 and S13 suggests the potential positive effect of support area on CLT punching shear strength.

The results also show that the round column increased the strength by 12%, which could be due to a more uniform stress distribution at the column edges when compared to a rectangular column where the stress concentration at column corners is higher.

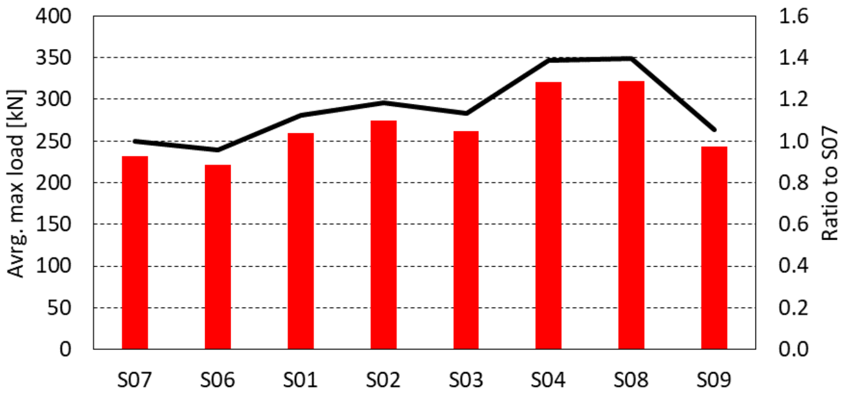

Figure 5: Impact of CLT provider, wood species, and CLT stress grade on punching shear strength

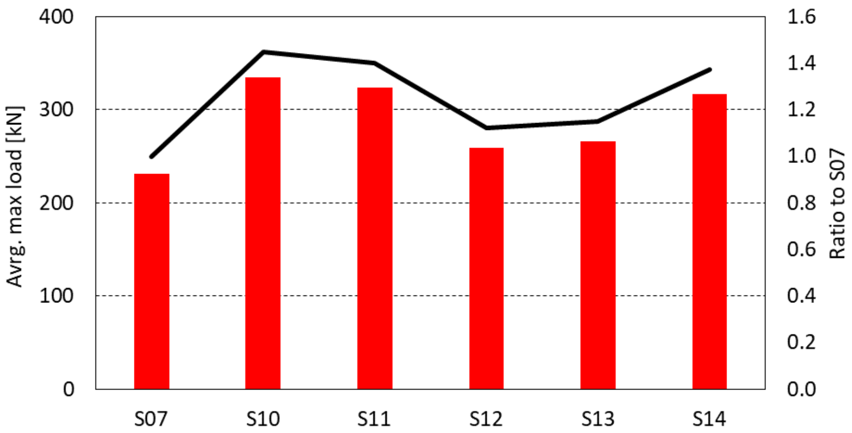

Figure 6: Impact of column shape and size on punching shear strength

Previous research on point-supported CLT shows that an effective width with an average load dispersion angle of 35° should be adopted in order to calculate the effective rolling shear strength under puncher shear conditions. In order to see if a larger effective width or support area can predict a higher punching shear strength, the results of different series with regard to these two parameters are compared in Figure 7. It can be observed that a bigger effective width does not always result in a higher capacity, but a larger support area can predict a higher capacity. The positive effect of the support area can also be seen in S04 and S05, where increasing the dimensions of the plate by 100 mm increased the overall capacity of the panel by 8%.

Finally, the results of the screw reinforced series normalized with respect to the similar unreinforced panel series are presented in Figure 8. The results show that the highest punching shear strength increase (41%) was achieved when a larger zone was reinforced (475 mm) with a tighter distance between screw rows (50 mm), resulting in more screws per each column face and having reinforcement in both directions (S18). Using a larger distance between the screw rows (80 mm) but reinforcing the same zone and in both directions (S19) increased the strength by 28% compared to the unreinforced series (S07). Keeping the distance between rows (80 mm) and having reinforcement in both directions but reducing the reinforced zone in S21 resulted in an 11% strength increase, which shows the effect of reinforcement zone length on punching shear strength. S20 and

S22 were only reinforced in the major axis direction but had the same level of reinforcement as S18 and S19. When the results of S18 and S19 are compared with S20 and S22, respectively, it can be observed that not having STS reinforcement in the minor direction reduced the increase in punching shear strength; however, the reduction was more pronounced for the case of higher STS reinforcement level.

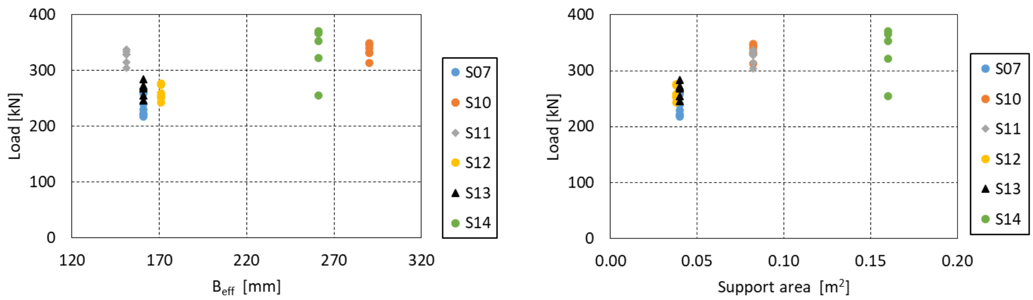

Figure 7: Impact of effective width (a); and support area (b) on punching shear strength

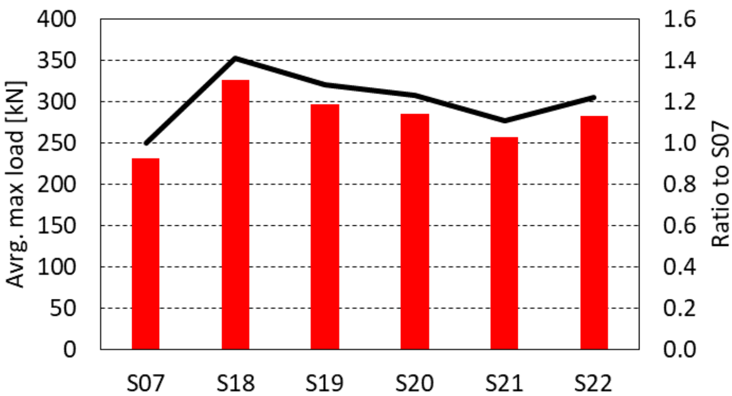

Figure 8: Impact of screw reinforcement on punching shear strength

3. Conclusions

The punching shear strength of CLT panels with interior edge-column, interior mid-panel, interior panel corner, and building perimeter conditions is being evaluated. Herein, the results of the first two column conditions are presented. Based on the results achieved to date and can be concluded that stress grade, species, column shape, column size, column location, thickness of load distribution plate, as well as self-tapping screw spacing, reinforcement zone length, and reinforcement direction impact the punching shear strength of point-supported CLT panels.

4. Acknowledgments

The project was supported by the Province of British Columbia's 'Green Construction Through Wood' program and the Natural Sciences and Engineering Research Council of Canada through an Alliance grant. The support by the UNBC technicians James Andal and Ryan Stern, as well as Fast + Epp Concept Lab manager Brandon Sullivan and Concept Lab technician Bernhard Zarnitz is appreciated.

5. References

[1] Karacabeyli, E, & Gagnon, S (2019) Canadian CLT Handbook, 2019 Edition. FPInnovations, Canada.

[2] Fast, P et al. (2016) Case study: An 18-storey tall mass timber hybrid student residence at the University of British Columbia, Vancouver. In proc. WCTE. Vienna, Austria.

[3] Zingerle, P et al. (2016) System solutions for point-supported wooden flat slabs. In proc. WCTE. Vienna, Austria.

[4] Ehrhart, T et al. (2015) Rolling shear properties of some European timber species with focus on cross laminated timber (CLT): Test configuration and parameter study. In proc. INTER. Šibenik, Croatia.

[5] Ganjali, H et al. (2023) Punching-shear strength of point-supported CLT floor panels. In proc. INTER. Biel, Switzerland.

[6] Muster, M (2020) Column-Slab Connection in Timber Flat Slabs. ETH Zurich.

[7] Mestek, P (2011) Punktgestützte Flächentragwerke aus Brettsperrholz – Schubbemessung unter Berücksichtigung von Schubverstärkungen. TU Munich.

[8] Mestek, P & Dietsch, P (2013) Design concept for CLT-reinforced with self-tapping screws. In Focus Solid Timber Solutions-European Conference on Cross Laminated Timber (CLT). Graz, Austria