Punching-shear strength of point-supported CLT panels

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1. Introduction

Cross-laminated timber (CLT) has gained popularity in recent years as a sustainable and cost-effective alternative to traditional 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 [2,3], shown in Figure 1 (left). In this system, the CLT panels are supported 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. One of the key strength properties in these applications is the CLT punching shear strength, which refers to its ability to resist concentrated loads or "punching" through the material, illustrated in Figure 1 (middle). CLT punching shear strength is directly related to the lamella rolling shear strength [4], which can be estimated through 4-point bending tests, or inclined in-plane shear test, as shown in Figure 1 (right). Previous research has shown that CLT punching shear is increased due to the confinement effect of lamellas from adjacent layers and the compression forces [5,6].

Figure 1: Point-supported CLT floor at Tall-Wood house (left); punching shear failure at column support (middle); rolling-shear failure (right)

2. Objective and methods

The current North American and European standards [7-9] do not provide guidance on the design of point-supported CLT floors. To address this knowledge gap, a research project is being conducted by Fast+Epp structural engineers in collaborations with the University of Northern British Columbia with the objective to develop design guidance for point-supported CLT floors. To achieve this objective, an experimental testing program is underway that consist of four phases: i) CLT rolling shear strength testing under in-plane shear and 4-point bending short-term loading; ii) CLT rolling shear strength and creep testing under 4-point bending long-term loading; iii) CLT panel punching shear testing; and iv) full-scale point-supported CLT continuous span floor testing.

The focus of this contribution will be on phases 1 and 3. In phase 1, a total of 13 series of both V and E stress rated 3-ply (89 mm and 105 mm) and 5-ply (139 mm and 175 mm) CLT specimens have been tested under inclined in-plane shear with 30 replicates per series on considering different grades and layer orientations. Furthermore, a total of 80 mid-scale 4-point bending tests on two representative CLT strength grades are underway. In phase 3, the punching-shear strength will be evaluated under variation of following parameters: a) support condition (columns at the panel centre, edge, and corner, as illustrated in Figure 2); b) CLT lamella species and grade; c) column support geometry; and d) level of screw reinforcement. Panels sized 1.7x1.8 m, 1.5x1.8 m, and 1.5x1.5 m will be used. Six repetitions per test series for a total of 180 specimens will be tested.

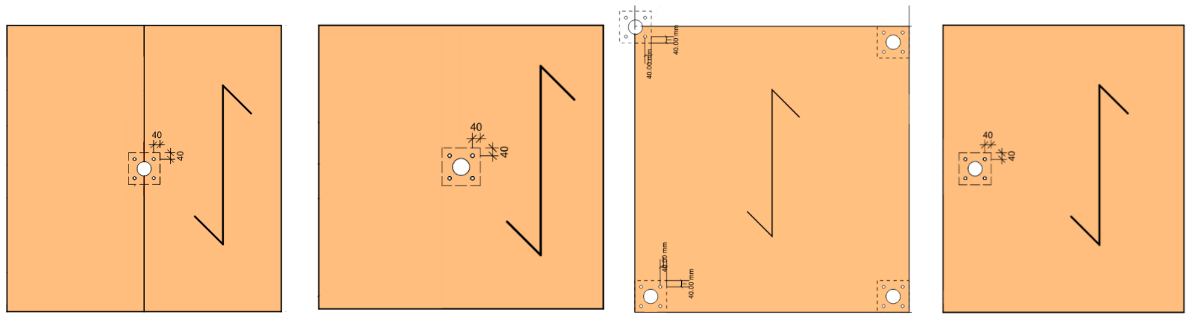

Figure 2: Punching shear test configurations from left to right: Interior panel edge condition, interior mid-panel condition, interior panel corner condition, and building perimeter condition

3. Preliminary and expected results

The average of the rolling shear strength values obtained from phase 1 in-plane shear tests varied from 0.94 MPa to 1.81 MPa with a coefficient of variation (COV) between 14% to 37%, which agrees with previous data. The average shear moduli ranged from 84 MPa to 157 MPa with COVs between 11% to 35%. The full paper will present a detail discussion of failure modes, impact of the parameters (strength grade and lamella thickness), and a comparison to the rolling shear strength values obtained from the 4-point bending tests. Furthermore, all results from the punching shear tests from phase 3 will be presented and discussed. Understanding the punching shear strength of CLT is crucial for successful and safe design of point-supported CLT floors. The findings from this research program will provide design guidance to practicing engineers and will be presented to the Technical Committee of CSA O86 for inclusion into the next edition of the Canadian Standard for Engineering Design in Wood.

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