Bending Properties of Connections in Cross Laminated Timber

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Summary

Cross Laminated Timber (CLT) is a class of plywood-like Engineered Wood Product (EWP) available in large thicknesses that is used mainly to create floor and wall slabs. This paper addresses performance of CLT panel edge-to-edge connections subjected to bending moments created by out-of-plane forces on floors or walls constructed from CLT panels of discrete width (circa 2 to 5m). Two types of connections employing self-tapping screws, half-lapped and single-spline, are investigated because they are compact and limit material wastage, and facilitate on-site construction operations. This study also investigates how placing washers under screw heads alters the strength and stiffness of studied connections.

Keywords: Bending Resistance; Connections; Cross Laminated Timber; Half-Lapped Joint; Single-Spline Joint; Self-tapping Screws; Washers.

1. Introduction

CLT is new generation of construction material available in large thickness. It has alternating laminations that usually are orthogonally arranged and adhesively bonded together. Consequently, CLT elements are tough against fracturing through their thickness making them capable of resisting effects of in-plane forces that easily split other types of Engineered Wood Products. CLT panels have comparable properties to lightweight Reinforced Concrete (RC) slabs, with a mass ratio of about 1:3 favouring CLT. Emphasis is on exploiting high stiffness- and strength-to-weight ratios of CLT in floor and wall applications. However, CLT panels cannot be used effectively without efficient and cost effective ways of fastening them together. This paper presents test data for bending strength and stiffness of mechanical connections between CLT plates made using self-tapping screws. Such data is important in respect of strength and serviceability performance limiting states of buildings. The two types of connections illustrated in Fig. 1 are investigated.

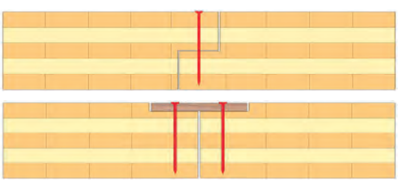

Fig. 1: CLT connections; top) Half-Lapped bottom) Single-Spline

2. Materials and Methods

The testing programme was designed to be performed with 5-ply (3 parallel and 2 orthogonal layers) CLT products manufactured in Europe and Canada. The tests were performed on specimens realized by jointing two CLT elements using ASSY 3.0 Eco-fast self-tapping screws manufactured by Würth. Screws had diameters of 6mm and 8mm. In some tests cup washers with inner diameters of 6.4mm (6mm screws) and 8.4mm (8mm screws) and outer diameters of 18mm and 25mm respectively were placed under screw heads. In single-spline tests, the spline elements were 18mm or 25mm thick Douglas fir plywood. Twelve series of connection tests were carried out using specially designed apparatus capable of applying a pure bending moment to connections at small displacements, Fig 2. At large displacements the applied forces approximated pure bending moments. Each test was

Fig. 2: Bending test apparatus

replicated three times. Since the configuration of single-spline joints are not symmetric, they were tested in two directions (top and bottom loading).

3. Results and discussions

Test data were analysed to determine engineering parameters that quantify the strength and stiffness of joints in connections. Half-lapped joints have equal behaviour for either top and bottom specimen loading, but single-spline joints have totally different behaviours under reversed loading because of their non-symmetric configurations. Analysis of data showed that half-lapped joints are superior to single-spline joints loaded from the top, but single-spline joints loaded from the bottom are superior to half-lapped joints. Placing washers under the heads of screws in half-lapped joints increased the values of maximum moment, yield moment, and initial stiffness by 18%, 69% and 43% respectively. Explanation of this lies in how addition of washers changed the deformation and failure mechanism. Fig. 3 shows typical post-failure deformations in half-lapped joint specimens with and without washers under screw heads. In both cases the failure mechanism involved plastic bending deformation of the screws on either side of the vertical joint plane. For half-lapped connections without washers the development of axial forces in screws was controlled by screw head pull-through resistance; but for connections with washers the heads of the screws were anchored effectively and axial forces in screws were controlled by screw thread withdrawal resistance.

Analysis of test data to evaluate the effects of using washers on single-spline joints revealed that loading them from the bottom enhanced performance relative to loading them from the top. Using washers in single-spline joints did not affect the initial stiffness considerably. The effects of adding washers were to enhance maximum moment and yield moment for specimens loaded from the top by 45% and 45%, and enhance those properties by 90% and 95% for specimens loaded from the bottom. In the case of single-spline specimens loaded from the top the relative anchoring characteristics of screws in head-side and point-side members were important. However, the failure mode associated with single-spline specimens loaded from the bottom were found to be different than those with half-lapped and single-spline specimens loaded from the top. Placing washers under the heads of screws in single-spline specimens loaded from the bottom significantly increases axial forces resisted by screws and rotationally restrained heads of screws, as illustrated in Fig. 3.

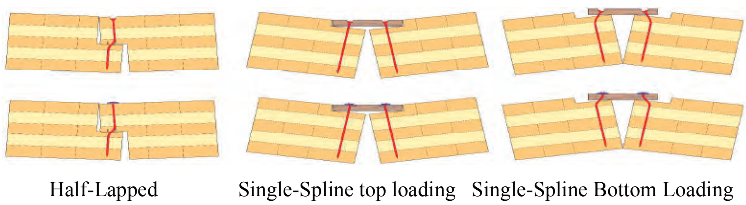

Fig. 3: Failure modes: top) no washer - bottom) with washer

4. Conclusions

The primary conclusions from this study are:

(1) In terms of resisting out-of-plane bending moments, the direction of the applied moment does not influence the behaviours of half-lapped joints. However, in the case of single-spline joints the direction of applied moment has a strong influence on their behaviours because of their lack of symmetry,

(2) When acting as plate edge-to-edge out-of-plane bending connections CLT half-lapped joints are strongest and stiffest when the moment causes tension in the spline plate.

(3) Both half-lapped and single-spline joints of types investigated are quite flexible and weak in their ability to resist effects of bending moments. Potential exists for improving designs of CLT connections made with self-tapping screws, while accounting for cost and construction practice implications of alterations.