EVALUATING ROLLING SHEAR STRENGTH PROPERTIES OF CROSS LAMINATED TIMBER BY TORSIONAL SHEAR TESTS

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ABSTRACT: This paper presents an experimental study to evaluate rolling shear (RS) strength properties of cross laminated timber (CLT) using torsional shear tests. The CLT plates were manufactured by polyurethane adhesive without edge-gluing. The test specimens were sampled from full-size CLT plates and processed into small annular specimens in order to achieve relatively uniform shear stress distributions in the cross layers under torsional loads. The influence of manufacturing parameters, such as, wood species and clamping pressure, on the RS strength properties of CLT was evaluated. By comparing the RS strength properties obtained from short-span bending tests, significant size effect on RS strength properties has also been observed.

KEYWORDS: Cross laminated timber, rolling shear strength, torsional shear tests, size effect

1 INTRODUCTION

Rolling shear (RS) stress in wood is defined as the shear stress in a radial-tangential plane perpendicular to the grain direction. Normally, RS strength of wood is fairly low compared with its longitudinal shear strength. In Eurocode 5 (2004), a characteristic RS strength value of 1.0 MPa is commonly used for wood independent of its strength class. For cross laminated timber (CLT) with crosswise board layups, high RS stresses may be induced in the cross layers under certain loading scenarios. For example, when a CLT floor is supported by columns, high concentrated loads may cause a shear critical zone around the supporting area; or high bending loads on short-span floors or beams may also cause high RS stresses. Therefore, it is important to understand the RS strength properties of CLT products subjected to heavy and highly concentrated out-of-plane loads.

In literature, very little research work has been reported on evaluating RS strength properties of CLT. The objective of this study is to evaluate the RS strength properties of non-edge-glued CLT plates by torsional shear tests. The influence of manufacturing parameters including wood species, lay-ups, and clamping pressure levels for curing adhesives on the RS strength properties is investigated.

2 METHOD

2.1 SPECIMENS

As shown in Fig. 1, three groups of CLT plates including 5-layer Hem-fir (HF5) plates, 5-layer Spruce-Pine-Fir (SPF5) plates, and 3-layer SPF plates (SPF3) were studied. Within each group, two clamping pressure levels (0.1 MPa representing vacuum press and 0.4 MPa representing mechanical press) were used to form the panels with polyurethane adhesive. Thus, a total of six different types of plates were investigated. For each type, three plate replicates were sampled. In the following context, if a HF5 plate is pressed under 0.4 MPa, it is denoted as HF5-0.4. Similarly, a 3-layer S.P.F plate pressed under 0.1 MPa is denoted as SPF3-0.1.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{full_size_clt_plates}
\caption{Full-size CLT plates for experimental studies}
\end{figure}

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Figure 2 shows the dimension of the annular specimens processed for the torsional shear tests. A CNC machine was used to process the annular shape of the cross layer.

![Figure 2: Annular CLT specimens for torsional shear tests](image)

2.2 Torsional Shear Tests

For each type of CLT plates, a total of 28 specimens were tested. Figure 3 shows the test setup of the torsional shear test in which the torsional moment was applied by a steel tubular beam which was firmly connected with one face layer of the CLT specimen. The other face layer of the specimen was fully restrained with the test table.

![Figure 3: Test setup of torsional shear test](image)

Figure 4 shows the typical rolling shear failure in the cross layer observed from the tests. The shear crack was developed with an inclined angle with respect to the plane of the layers. Figure 5 shows the calculated rolling shear properties using the torsional shear formula and the recorded peak torsional loads.

![Figure 4: Rolling shear failure mode](image)

Figure 5 shows the calculated rolling shear properties using the torsional shear formula and the recorded peak torsional loads.

![Figure 5: Cumulative distributions of rolling shear strength](image)

3 CONCLUSIONS

- The experimental results indicated significant variability in the RS strength distributions among the CLT specimens due to the relatively low grade wood boards used in the cross layers.
- The thickness of cross layers seems to affect the RS strengths of CLT significantly since the SPF5 specimens with thinnest cross layers had significantly higher RS strength than the other types of specimens.
- It seems that the clamping pressure to cure the adhesive did not affect the RS strength properties significantly.
- Compared with the rolling shear strength properties established by short-span bending test data of CLT specimens (Li, et al. 2013), significant size effect was found due to the different volumes of wood stressed in rolling shear.

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