SCREWED JOINTS IN CROSS LAMINATED TIMBER STRUCTURES

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ABSTRACT: Approximately 60% of all joints in solid timber structures assembled with Cross Laminated Timber (CLT) are realised with screws. Although, the behaviour of axially loaded self-tapping single screws is already well known, only minor experiences are available regarding the behaviour of screwed wall joints. Furthermore, since seismic resistance of CLT structures depends to a great amount on the connections’ ability to dissipate energy, it is important to extend the knowledge on their behaviour more thoroughly. This paper gives a brief overview of the results obtained from experimental monotonic and cyclic tests that were carried out not only on screwed CLT single joints, but also on wall tests with screwed joints. Additionally, the question on modelling the behaviour of a screwed wall joint based on the behaviour of a single screw will be discussed within the present contribution as well. Aforementioned tests are part of an extensive ongoing study investigated at the Graz University of Technology, Institute of Timber Engineering and Wood Technology (TU Graz) and at the competence centre holz.bau forschungs gmbh (hbf).

KEYWORDS: Timber, CLT, Connections, Screws, Cyclic tests

1 INTRODUCTION

Investigations done in the last 15 years showed that screwed joints are an indispensable part of modern timber engineering. Nevertheless, even if approximately 60% of all joints within a CLT building are screwed, a suitable model for calculating the screwed wall joints is not available and only minor amount of adequate information regarding its behaviour was found.

Extensive experimental program carried out at TU Graz which is focused on this topic encompasses following three steps: (i) single joint tests, (ii) wall tests, and (iii) a full scale shaking table test of a three storey CLT building.

Focusing on step (i), beside presenting certain test results, within this paper we will also compare selected models used for calculation of joints with fully threaded self-tapping single screws in CLT elements. Furthermore, the results of the wall tests will be presented and compared with the load carrying capacities calculated with an adapted wall model.

2 METHOD

All single joint configurations were tested both monotonically and cyclically, loaded in shear and/or tension. The wall tests were arranged in such a manner that the behaviour of wall systems with different connection types can be analysed using characteristics of certain connections from step (i). Altogether, 215 single joints and 17 walls were tested within these two steps, whereby more than 50% of the tests were carried out on screwed joints.

However, present contribution focuses on wall/floor single joints loaded in tension or shear (Figure 1a). Parameters varied were the type of used screws (fully- or partially threaded screws, FT or PT respectively) and the screw-load angle (\(\alpha = 90^\circ\) and 45\(^\circ\)).

Calculations that were used for comparison with the test results are based on Johansen’s equations including the “rope effect” as defined in [1], simplified suggestion given by Blaß & Bejtka [2] an detailed calculation suggested by Bejtka & Blaß [3].
Figure 1b shows the setup of the wall test where wall|floor joint was assembled with FT screws. The monotonic and the first cyclic test were performed with a vertical load amounting to 20.8 kN/m and the second cyclic test with 5.0 kN/m.

New model was created in order to adapt existing calculation models given for CLT joints with angle brackets and hold-downs so that it could be applied on screwed joints as well. The results of the single joint tests from step (i) were used as an input for this calculation.

3 RESULTS AND DISCUSSION

Basic ratios, such as maximum load ($F_{max}$), stiffness ($K_{ser}$), ductility ($\mu$) and – from the cyclic tests obtained – ‘impairment of strength’ ($\Delta F$) and the equivalent viscose damping ratio ($v_{eq}$) were calculated for all tested configurations.

In comparison with axially loaded screws, screws loaded laterally showed lower stiffness and load carrying capacity, but considerably higher deformations, impairment of strength and damping ratio (see Figure 2).

Comparison of test results with calculation models showed that they generally underestimate the load carrying capacity of single screws.

Tests on screwed wall joints provide comparable maximum loads to configurations with angle brackets and hold downs. Furthermore, a high stiffness and high ductility ratio of the screwed joint in relation to the other configurations has been noticed. Further results and interpretations regarding the wall tests carried out at TU Graz are given in [4]. However, results lead to conclusion that both the bottom joint with angle brackets and hold-downs as well as the screwed top joint has to be considered in an adequate way.

Results of the calculation model given in Table 1 show good accordance with the test results if the assumed point of rotation (PoR) is put in the centre of the base line of the wall. Otherwise, with a higher distance, the load carrying capacity of the wall is overestimated.

<table>
<thead>
<tr>
<th>$q$</th>
<th>PoR</th>
<th>rocking</th>
<th>shear</th>
<th>test</th>
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<tr>
<td>[kN/m]</td>
<td>[m]</td>
<td>[kN]</td>
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<tr>
<td>20.8</td>
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<td>51.65</td>
<td>129.02</td>
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The last part of the present paper deals with a model that can be used to describe the load-displacement curve of a laterally loaded CLT wall based on the characteristics of its connections. Thereby, an analytical model [5] which describes the non-linear behaviour of a single screw is used. The positive results of the first trials encourage further research on this topic.

4 CONCLUSIONS

The present contribution provides improved insight into the behaviour of screwed joints as part of CLT-structures. This behaviour is described by some basic ratios given for different configuration types. Furthermore, the behaviour of walls with screwed joints is presented as well. Finally, an analytical model describing the behaviour of single screws is used to simulate the load-displacement curve of a wall test with a screwed joint.

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REFERENCES