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Experimental study of the lateral resistance of timber shear walls

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Context

The study focuses on nail laminated timber (NLT) shear walls and their modeling with a commercial design software, based on connection tests. NLT shear walls can easily be manufactured and present a high vertical resistance. Nevertheless, today nail laminated timber is more commonly used for floor and roof systems. Therefore, NLT shear walls are much less investigated so far. One of the few studies on NLT shear walls is done by Zhang et al. from the Timber Engineering and Applied Mechanics (TEAM) research group at University of British Columbia (UBC). They studied the behavior of NLT shear walls with a series of full-size tests to investigate different parameters. This study is used in this work to evaluate the developed model.

Connection tests

The investigated NLT shear wall type has two main connections, the sheathing connection (figure 1 right) and the NLT connection (figure 1 left), which were studied in detail.

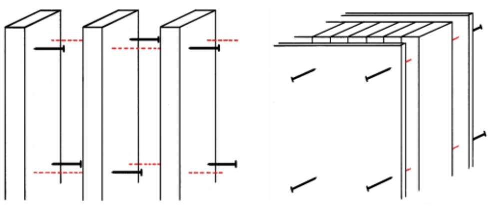

Figure 1: Nail laminated timber: NLT connection (left), sheathing connection (right)

Because of the cyclic loading that a shear wall typically must resist (wind loads, seismic loads), both monotonic and reversed cyclic loading tests were carried out. For this reason, 4 different test groups with 2 series of tests each (one series of monotonic loading tests and one series of reversed cyclic loading tests) were proposed in a first step. The groups 1 to 3 are sheathing connection tests with smooth nails, ring nails and screws with a big head as fastener types. The nail connections of the NLT form the 4th group. In a second step, a group of NLT connection tests (group 5) was added. The aim of this group was to get an idea of the influence of friction on the stiffness and the resistance of the connections. Two series of specimens were investigated under monotonic loading, one with Teflon sheets between the timber elements and one without. All 5 groups were tested under shear loading parallel to grain. For each series, 6 specimens were tested.

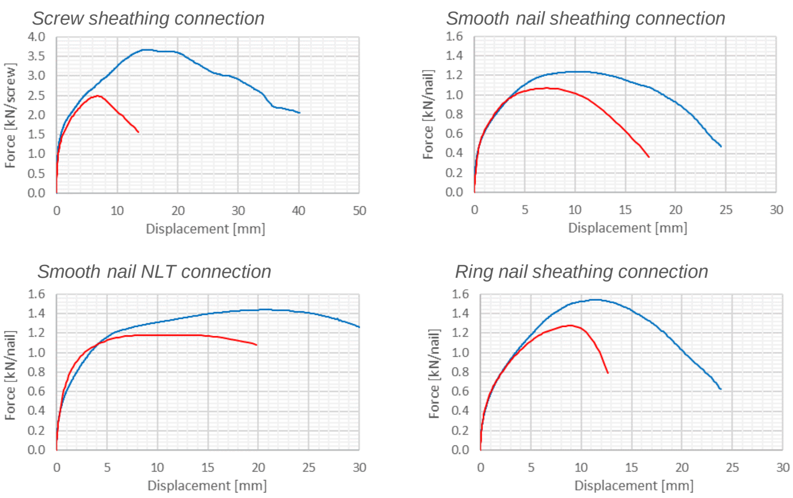

Figure 2: Comparison of the monotonic (blue) and reversed cyclic (red) loading tests

The reversed cyclic loading tests and the monotonic loading tests of the three nail connections showed almost identical results until around 80% of the monotonic loading peak load. The NLT connections presented a good ductility even under reversed cyclic loading.

The nail sheathing connections presented a similar response under monotonic loading (same displacement, 26% higher peak load for ring nails). Under reversed cyclic loading however, the ring nails showed a rather brittle behavior compared to the smooth nails but still achieved a 20% higher peak load. The screw sheathing connection presented a lot of brittle failure modes under monotonic loading and a considerable loss of ductility under reversed cyclic loading. Friction contributes to the peak load of the NLT connection to about 14% and even to about 20% at 40% of the peak load.

Design and numerical modeling

A basic model was developed with RFEM, a commercial static software of Dlubal and calibrated with the experimental results of NLT shear walls provided by Zhang et al. The figure below shows the developed model, which consists of beam elements representing the NLT (red), surface elements representing the sheathing (green), rigid elements representing the nails (blue), and springs representing the behavior of the nailed connections. The wall is connected to the bottom and the top floor with angle brackets and hold downs, which are modeled with springs. The hypothesis is made that the NLT connections and the sheathing connections will be the most ductile and weakest part of the wall. Therefore, the timber elements, the hold downs and the angle brackets are modeled with a linear elastic behavior.

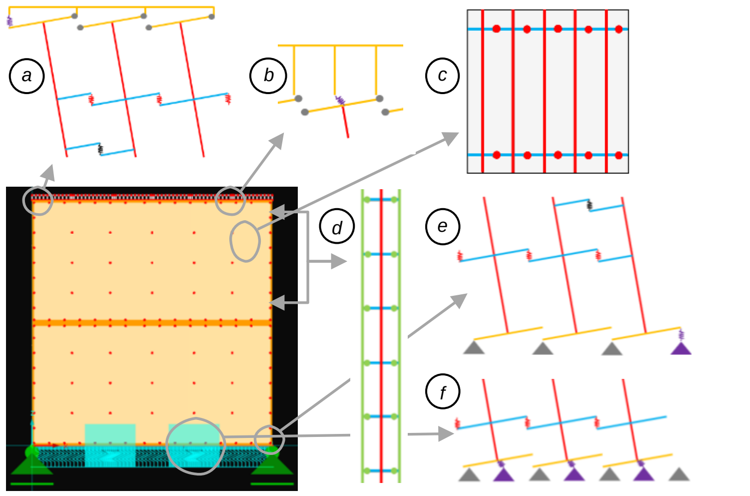

Figure 3: Schema of the NLT shear wall model: beam elements, which represent the timber pieces (red), stiff elements, which represent the nails (blue), help elements to model the width of the timber elements and the top floor (loading beam) (orange), and springs, which represent the behavior of the connections: NLT connections (red), hold downs and angle brackets (purple), NLT connection hold down nails (black), floor connections (grey); a: hold down top floor, b: lag strew, c: NLT, d: sheathing panels, e: hold down bottom floor, f: angle brackets

The model showed that by adapting the nail pattern and/or the sheathing configuration, a wide range of resistances can be achieved. Furthermore, design values were calculated for the NLT wall with smooth nail sheathing connections. Based on these values, a 5-story building was designed. A horizontal load of 315 kN can be borne by 6 NLT walls. The seismic analysis of the 5-story building showed that with a fundamental period of 2.00s, the building only needs to resist about 153 kN. This low seismic load is mainly possible because of the high ductility this type of wall systems can generate.

Conclusion

The simple construction and the adaptability in terms of resistance of the nail laminated timber shear walls are interesting properties for seismic applications. The developed model can be used for a predesign. However, it should be based on additional test data for a final design.