Connection stiffness and vibration transmission in timber frame structures

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Timber-frame structures are widely used in Sweden for the construction of single-family houses but also for apartment buildings of up to four floors. The production of timber buildings is using a high degree of prefabrication, for both office and residential purposes. Floor and wall panels are manufactured in workshops under controlled conditions. The jointing of these elements needs to fulfill functions such as load transfer, tightness and sound insulation.

Two joint projects investigated the connections between floor and wall elements in such timber frame structures in an experimental study of the static and dynamic performance under serviceability loading [1]. Manufacturers delivered multiple different variants of their systems (four in total) of two different types: with the walls standing on top of the floor as well as with the floor attached sideways to the wall. The elements used original dimensions, choice of materials and connectors whilst the overall dimensions were reduced in order to fit the test machine (see Figure 1, left, for an overview of one of the set-ups). Modifications to the base-variants led to in total 13 different set-ups. Thereby, parameters such as the number and spacing of the connector screws, additional vertical dead weight or the influence of a silicone bond on the connection area were varied.

In the dynamic tests, the floor elements were excited in a frequency sweep between 10-150 Hz. In total 21 accelerometers on the wall and floor recorded the response of the structure. In the static tests, the wall elements was loaded inwards with local measurement devices positioned in the joint region as well as a contact-free displacement measurement system at the backside.

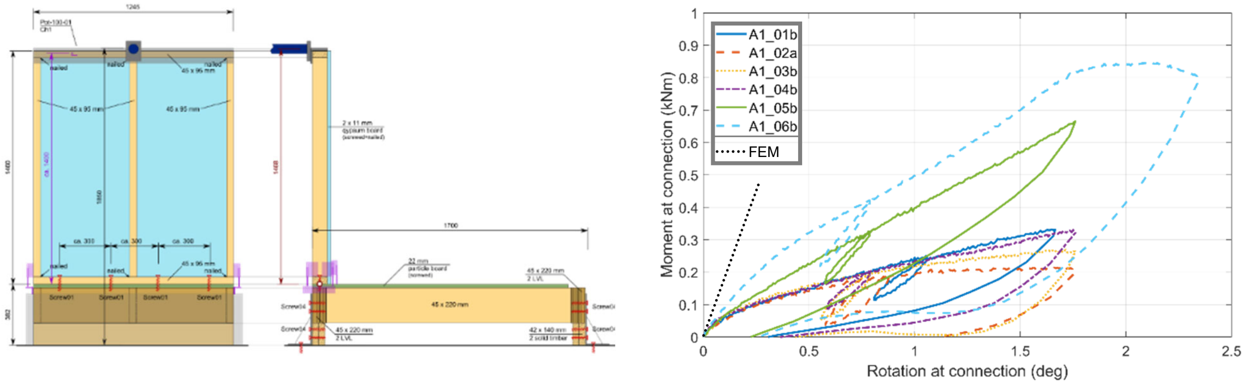

Figure 1: Geometry of one of the set-ups (left) and the moment-rotation curves for the variants of the same setup (right).

The results of the static loading were the moment-rotation curves from which the rotational stiffness in the connection was determined (see Figure 1, right, for one of the set-ups); the results from the dynamic loading were eigenmodes and the insertion loss. The positioning and the number of screws in the variants did not have a significant influence on neither the static nor the dynamic performance for the set-ups with the wall on top of the floor elements. The weak point in the set-ups was the nailed connection between the bottom rail and the vertical studs. Replacing these with screws increased stiffness significantly. A general conclusion is that a stiffer connection is less optimal for transmission of vibrations (and vice-versa). Still, this may not be generalized to other situations and dimensions of such structures.

Finite Element simulations were performed additionally using Abaqus. The model recreates the static experiments by using solids for the timber parts as well as the wall sheeting and the flooring. Contact behavior with friction is introduced between all parts of the model. Connectors such as screws and nails are modelled using beam elements using embedded region constraints for connecting them to the individual parts. The initial stiffness of the connection in the very beginning of the loading can be reproduced with the numerical model and the applied simulation techniques. Nevertheless, it becomes obvious that the actual behavior is non-linear from a very early stage on, most likely due to the behavior of the nails/screws in the connection between the studs and the bottom rail.

References

[1] Schweigler, M., Bolmsvik, Å., & Dorn, M. (2018). *Static and dynamic properties of connections in timber-frame structures: BOOST + FBBB project*. Linnaeus University, Faculty of Technology Department of Building Technology

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