EXPERIMENTAL ASSESSMENT OF THE LOAD DISTRIBUTION IN MULTI-DOWEL TIMBER CONNECTIONS

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Abstract: An integrative, hierarchically organized testing procedure for the quantification of the load distribution in multi-dowel timber connections is presented herein. The use of contactless deformation measurement systems allowed the combination of test data from single dowel and multi-dowel connections, which gave access to the loads acting on each dowel over the full loading history. As a consequence of the anisotropic material behavior of wood, a non-uniform and progressively changing load distribution among the dowels was found.

1. Introduction

If properly designed, dowel connections exhibit high ductility, and consequently, a highly non-linear behavior, which has its origin in permanent deformations of steel dowels in bending and of wood under embedment stresses. This slip behavior of connections causes relative displacements between the connected elements. A single-dowel transfers loads only perpendicular to the dowels' axis. Hence, only in dowel groups it is possible to transfer bending moments, which is split into loads on the individual dowels with different orientation. The orientation is particularly important for timber, since wood exhibits anisotropic behavior as a consequence of its cellular microstructure. Hence, the load-displacement behavior of single dowel connections depends on the load-to-grain orientation. This in turn affects the distribution of loads among a group of dowels, which is investigated in this integrative and hierarchically organized study.

Double shear steel-to-timber connections, which are widely used in practical applications, were chosen. Steel dowels were made of heat treated steel of quality S235 with diameters of 12 and 20 mm. The timber elements were made of Laminated Veneer Lumber (LVL) composed of parallel oriented spruce veneers. In order to avoid premature splitting of the LVL and to allow for large dowel displacements, connections were reinforced with self-tapping screws.

Mechanical tests were performed on various scales and levels, as outlined in Fig. 1. In a first step, mechanical properties of the individual components of dowel connections, namely the LVL and the steel dowel itself, were investigated. Material properties of steel dowels were measured in tension as well as in bending tests in order to quantify their moment-rotation characteristics, i.e. their ductility. Full-hole embedment tests were conducted for various load-to-grain orientations and the two different dowel diameters. In a next step, single dowel steel-to-LVL connections with a double shear layout were tested, again, for different load-to-grain orientations. Finally, dowel groups were exposed to bending moments in a 4-point bending test setup.

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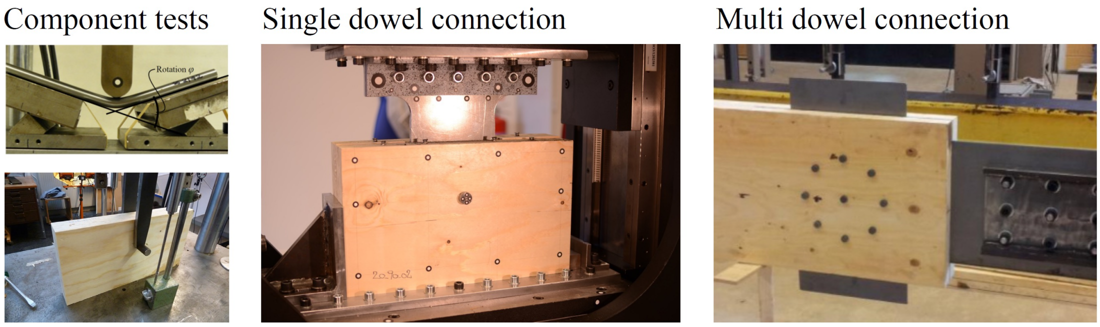

Figure 1. Hierarchically organized experimental program from component tests up to multi-dowel connections.

2. Results

As expected, relative rotation capacity, with relative rotations of up to 7° were measured in the multi-dowel connection tests, for both dowel diameters. The relative rotation was followed by a contactless optical measurement system. In addition, the same system was used to monitor displacements of the individual dowels. This gave access to the relative displacement of each dowel at the loaded steel plate, as well as to its bending deformation. The same characteristics were also measured in single dowel tests. As regards multi-dowel steel-to-timber connections, the relative displacement of the dowels was uniform among the dowels and enforced by the loading through the steel plate. Thus, the relative rotation of the multi-dowel connection could be related to dowel displacements, and consequently, since the same quantity was measured in single dowel tests, to single dowel loads. Performing this combination for each measurement point gave access to the load distribution among dowels over the entire loading history of the multi-dowel connection.

3. Conclusions

The load distribution in multi-dowel connections could be assessed and quantified by an integrative and hierarchically organized experimental campaign. It was demonstrated that the anisotropic material behavior of LVL, and consequently of wood in general, leads to a non-uniform distribution among the dowels. This was well visible in connections with dowels in a circular arrangement, where each dowel had the same distance to the center of the relative rotation. In the quasi-elastic domain, dowels loaded parallel to the grain were found to be highest loaded, while dowels loaded perpendicular to the grain were least loaded. The distribution of loads changed with increasing relative rotation. This effect could be related to the hardening effect in wood when loaded with an angle or perpendicular to the grain.

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References

[1] T.K. Bader, M. Schweigler, G. Hochreiner, E. Serrano, B. Enquist, M. Dorn. Dowel deformations in multi-dowel LVL-connections under moment loading. *Wood Mater Sci Eng* 2015.
[2] T.K. Bader, M. Schweigler, G. Hochreiner, B. Enquist, M. Dorn, E. Serrano. Experimental characterization of the global and local behavior of multi-dowel LVL-connections under complex loading. *Mater Struct* 2015.
[3] T.K. Bader, M. Schweigler, E. Serrano, B. Enquist, M. Dorn, G. Hochreiner. Integrative experimental characterization and engineering modeling of single dowel connections in LVL. Submitted to Constr Build Mater 2015.