TIMBER MATRIX FAILURE MODES IN MULTI-DOWEL CONNECTIONS

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Abstract: The engineering design of dowel type steel-to-timber connections is comprehensive and shall also include the surrounding timber matrix, as required by the principles specified in Eurocode 5. As one part of a hierarchically structured research program, the loading and failure modes of multi-dowel connections has been investigated, including both the elastic as well as the cracked domain of the load history. Depending on the presence of local reinforcement, in order to prevent premature brittle failure and to insure local ductile dowel behavior, the global response became more or less ductile. The monitoring of surface deformations of the timber by means of a contact free displacement measurement system (DIC) supported the identification of stepwise changing structural systems. This data constitutes a valuable basement for the completion resp. improvement of the present design procedures with respect to consistency and effectiveness.

1. Introduction

The present version of the design code for timber structures (Eurocode 5, EC5) contains design rules related to timber matrix failure modes due to connectors (EC5 6.5 *Notching*, EC5 8.1.4 *Loading at an angle to the grain*, EC5 Appendix-A *Tensile and shear* b*lock failure*). However, design procedures for a dowel group loaded by bending moments or by a combination with normal resp. shear forces are missing.

As part of an integrative research work [1,2,3] on dowel-type connectors, 4-point-bending tests (Fig. 1) have been performed and documented by a contact free displacement measurement system (DIC) along the whole loading history. The test program included circular and rectangular arrangement of the dowels with two diameters of 12 mm and 20 mm. In order to support effective interpretation of the results, undisturbed by any growth irregularities, Laminated Veneer Lumber (LVL) plates with a thickness of 51 mm were used as side members. Most of the test samples were reinforced by self-tapping screws perpendicular to the grain just to guaranty ductile behavior.

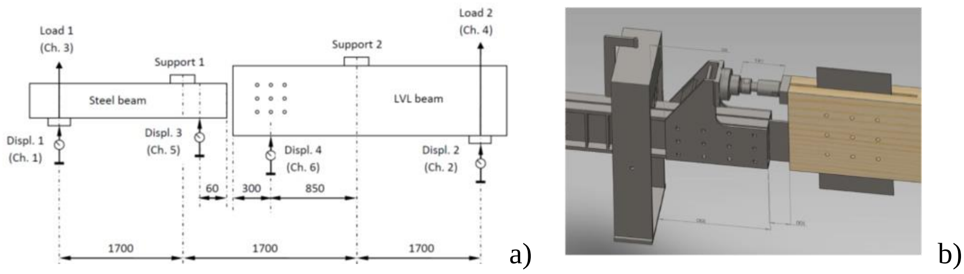

Figure 1. Test configurations: a) moment only and b) moment with normal forces.

2. Results

The DIC measurement system proved to be a powerful tool for the illustration of several aspects and findings:

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a) Assignment of cracking events to the nonlinear global system response (see Fig. 2): The sequence of crack formation is indispensable for the assignment of the corresponding structural system in the context of engineering modelling.

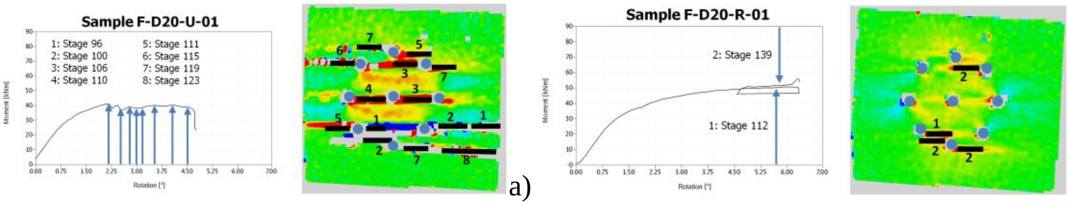

Figure 2. Cracking history: a) unreinforced and b) reinforced test samples.

b) Identification of the reason for final failure (instability, reduction of the internal leverage of forces, kink-banding parallel to the grain at the area of load transfer …)

c) Strain fields (parallel and perpendicular to the grain, shear) in the vicinity of single dowels (Fig. 3a) as well as across the affected area of the dowel group (Fig. 3b). These results are valuable for the validation of subsequent numerical engineering models.

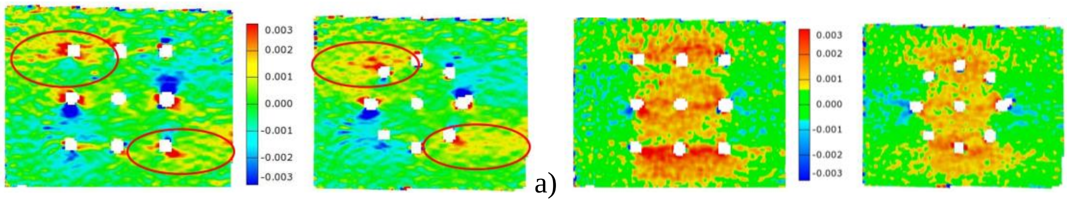

Figure 3. Strain fields: a) strains perp. to the grain (=vertical) and b) shear strains.

Beyond the elastic domain, nearly a continuous redistribution of loads among the single dowels, due to plasticity, hardening and crack formation, could be observed.

3. Conclusions

The nonlinear load carrying behavior of the individual dowels seems to have an important impact on the failure mode of the surrounding timber matrix. Additional verification steps have to be included into the present design procedure of EC5 also taking into account upper and lower limits for the load carrying capacity in un-cracked and cracked modes. The corresponding slip curves in terms of moment-rotation relationship - needed for the numerical modelling of connectors in the context of structural engineering of timber structures – have to be adopted depending on the type of detailing (± reinforcements, distance among individual dowels) and the extent of acceptable ductility.

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