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THE INFLUENCE OF DISPLACEMENT BOUNDARY CONDITIONS ON THE EMBEDMENT BEHAVIOR OF DOWEL-TYPE FASTENERS

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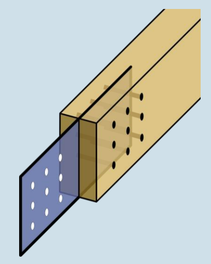
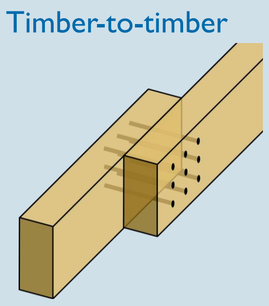
Motivation

In dowel connections, loads can either be transferred directly from timber-to-timber elements, or indirectly via an intermediate steel plate. The latter ones are so-called **steel-to-timber** connections, where the loading directions of the single dowels in a dowel group, are prescribed by the displacement of the quasi-rigid steel plate. In this case, the embedment behavior underlies a prescribed (constrained) displacement boundary condition. On the contrary, loading in **timber-to-timber** connections is close to an unconstrained displacement situation.
Due to the inherent, **anisotropic** mechanical nature of wood, significant differences in the embedment behavior, between loading at different **angles with respect to the grain direction,** α, in combination with different **displacement boundary conditions**, are observed. The latter two influence parameters are experimentally investigated by means of embedment tests in this study.





Materials & Methods

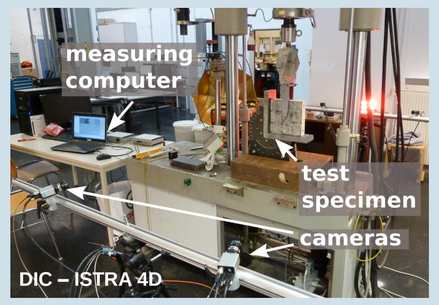
GENERAL PRINCIPLES

- Full-hole embedment tests according to EN 383 [1]
- Same materials for both test series – screw reinforced laminated veneer lumber (LVL) with parallel veneers and steel dowels of hardened steel
- Dowel diameter d=12 (and 16 mm); LVL specimen width 51 mm
- Climatic conditions: 20°C and 65% RH
- Displacement controlled loading up to at least twice the dowel diameter, including two unloading cycles, at seven different load-to-grain angles (α)

DEFORMATION MEASUREMENT TECHNIQUE

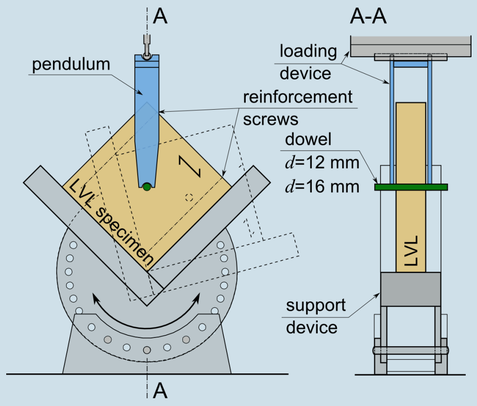
Non-contact deformation measurement system based on digital image correlation (DIC)

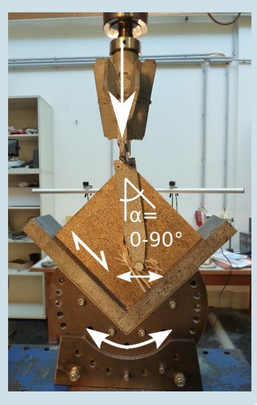
- Unconstrained: 2 pairs of 5 mpx cameras (ISTRA 4D, Dantec Dynamics)
- Constrained: 1 pair of 12 mpx cameras (Aramis, GOM)



UNCONSTRAINED DISPLACEMENT BOUNDARY CONDITION [2]

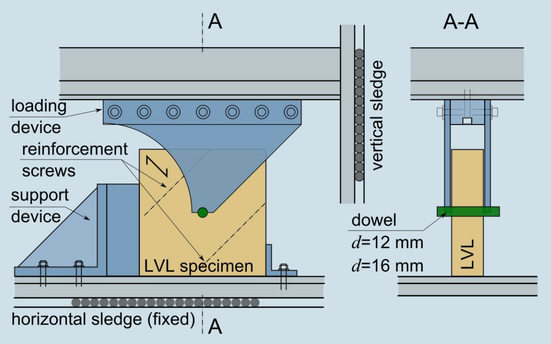
- Uniaxial test setup (pendulum)
- Only vertical reaction force
- Vertical and lateral dowel displacement

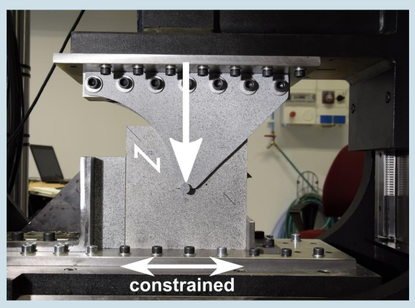




CONSTRAINED DISPLACEMENT BOUNDARY CONDITION

- Biaxial test setup
- Vertical and lateral reaction force
- Only vertical dowel displacement





Results & Conclusions

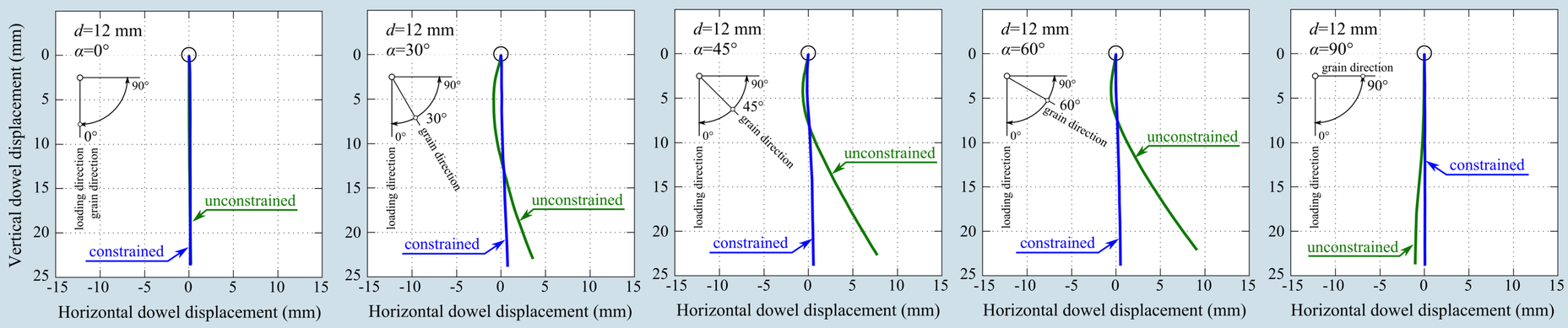
DISPLACEMENT BEHAVIOR

Unconstrained loading:

- Nonlinear dowel displacement path
- Change in sign of lateral displacement
- Lateral dowel displacement up to 9 mm (d=12 mm, α=60°)

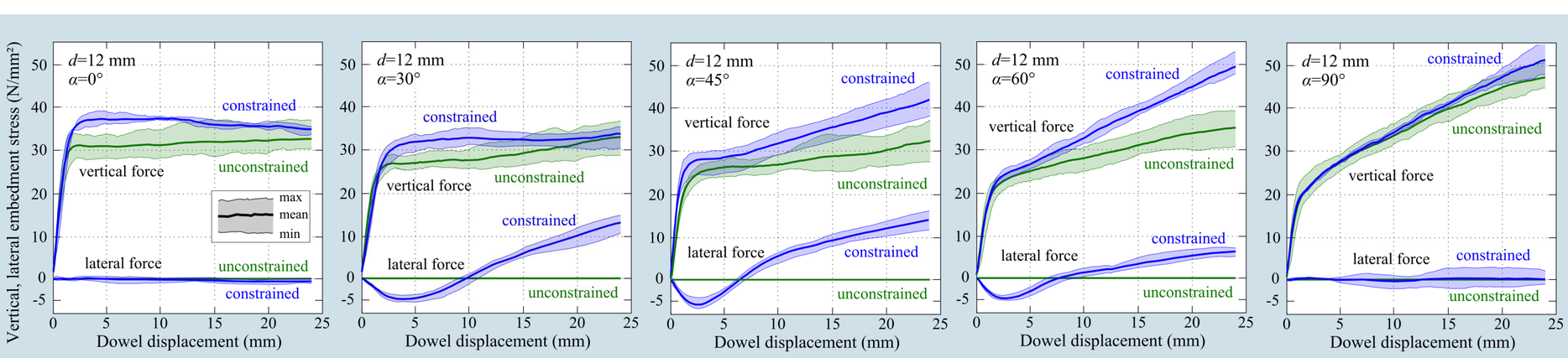
Constrained loading:

- Almost vertical dowel displacement path
- Small lateral displacements due to compliances in the test setup

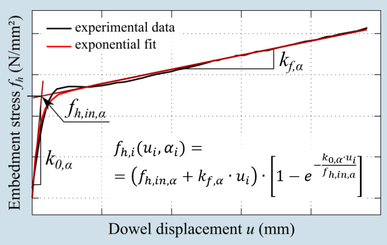


LOAD-DISPLACEMENT BEHAVIOR

- Pronounced nonlinear load-displacement behavior with high ductility
- Considerable hardening for load-to-grain angles larger than 45°
- Higher embedment stresses for loading under constrained boundary conditions
- Lateral reaction forces of up to 14 N/mm² (d=12mm, α=45°) for unconstrained loading

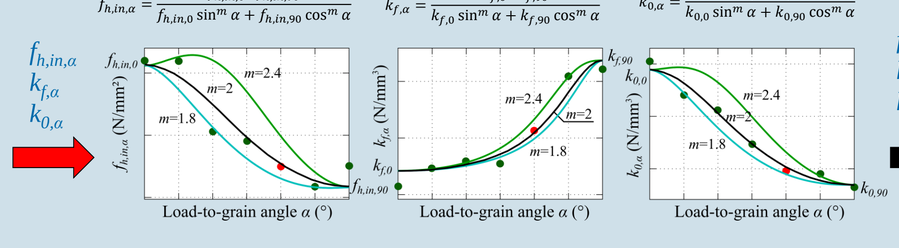


PARAMETERIZATION

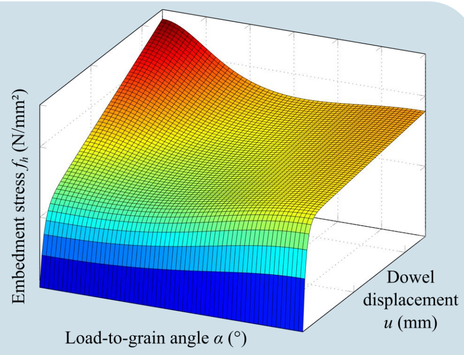


1st step: Fit of single slip curves for each load-to-grain angle (α), using exponential regression function presented by Foschi [3]

$$f_{h,in,\alpha} = \frac{f_{h,in,0}\cdot f_{h,in,90}}{f_{h,in,0}\sin^m\alpha + f_{h,in,90}\cos^m\alpha} \qquad k_{f,\alpha} = \frac{k_{f,0}\cdot k_{f,90}}{k_{f,0}\sin^m\alpha + k_{f,90}\cos^m\alpha} \qquad k_{0,\alpha} = \frac{k_{0,0}\cdot k_{0,90}}{k_{0,0}\sin^m\alpha + k_{0,90}\cos^m\alpha}$$



2nd step: Regression of the three coefficients from step 1 over α (Hankinson [4])



3rd step: Application of regression function from step 2 on step 1

References:
[1] EN 383, 2007, Austrian Standards Institute.
[2] Schweigler et al., 2016, submitted to Construction and Building Materials.
[3] Foschi, 1974, Wood Science.
[4] Hankinson, 1921, Air Force Information Circular.

Acknowledgements:
The financial support to Michael Schweigler, through a Short Term Scientific Mission of COST Action FP1402 (Basis of Structural Timber Design – from research to standards), is gratefully acknowledged.