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EMBEDDING BEHAVIOUR OF DOWEL TYPE CONNECTORS IN WOOD INTERPRETATION OF EXPERIMENTAL FINDINGS

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MOTIVATION

Focus of interest:

- ❑ Reasons for linear course of hardening
- ❑ Knowledge about elastic limit and cracking mechanisms
- ❑ Size of affected area and the characteristic of the local strain field

Experimental assessment:

- ❑ Fields of displacements at different load steps >> "history" of crack formation
- ❑ Due to no splintering at the surface assessment of results from the mid-plane by cutting of the specimen

TEST SETUP AND GLOBAL SYSTEM RESPONSE

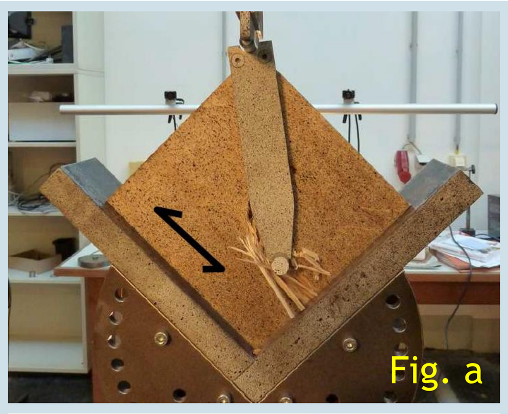


Fig. a

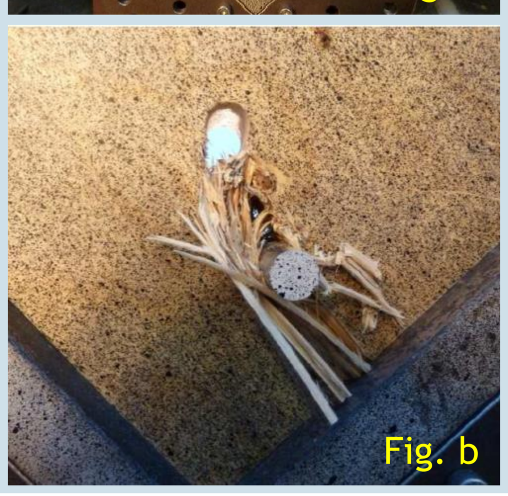
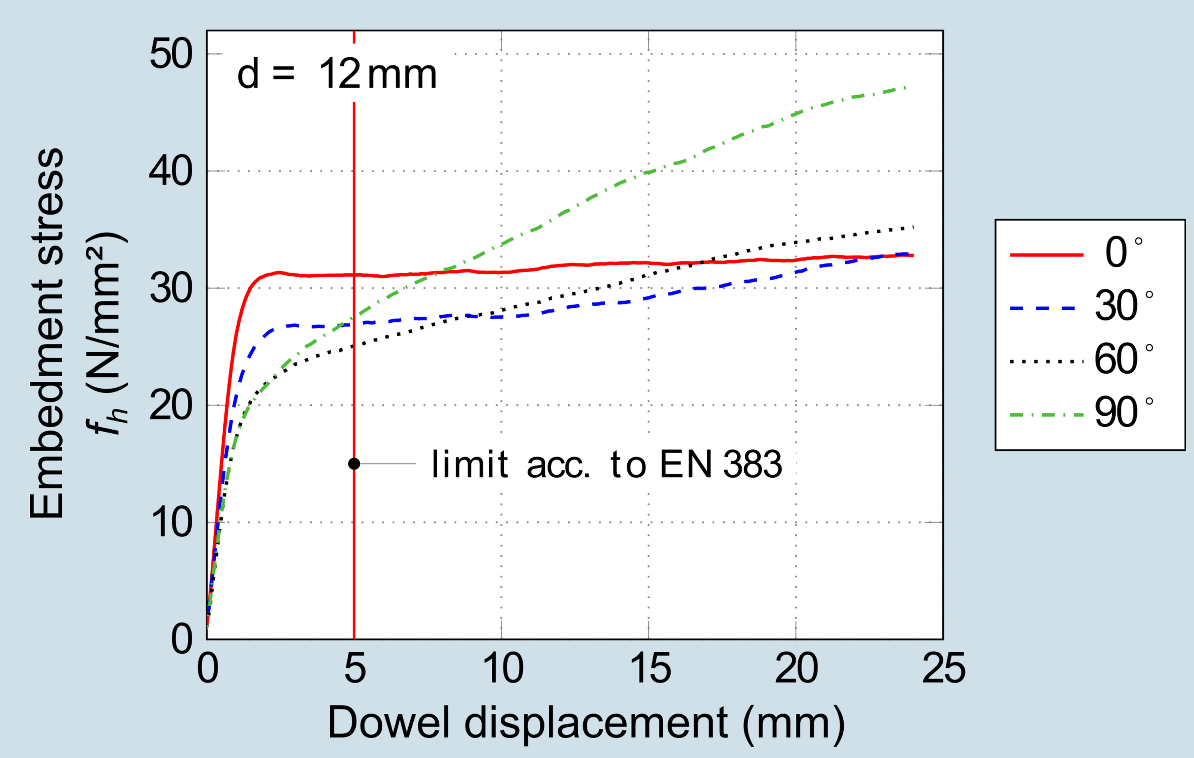


Fig. b

Embedment test-setup

- ❑ Embedment tests according to EN 383:2007 (Fig. a) with extensions:
  - ✓ displacements >> 5mm
  - ✓ unconstrained
  - ✓ constrained (load-direction = displacement-direction)
- ❑ Test samples were prevented from premature splitting by reinforcements (full threaded screws). No contact to the dowel
- ❑ Clear wood substituted by LVL (Kerto-S)
- ❑ 51mm for both M12 resp. M16 to reduce the impact of lateral splintering

Global system response



Typical load displacement curves:

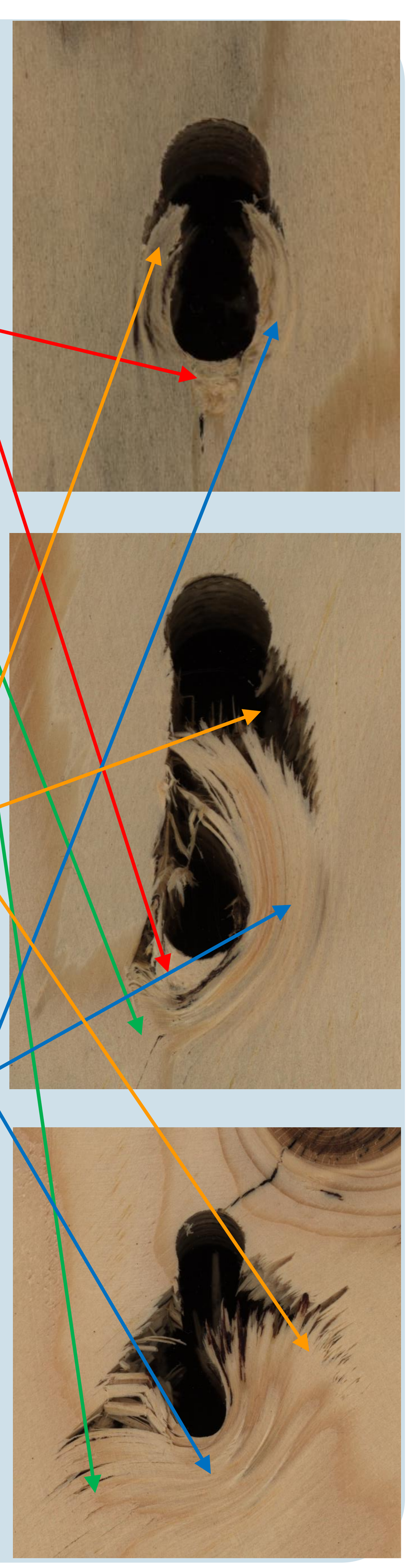
- ❑ Smooth slip curve every time
- ❑ Decreasing elastic stiffness with increasing load-to-grain angle
- ❑ Increasing strength with increasing load-to-grain angle and relative dowel displacement (≈2x Φ)
- ❑ Approximately linear course of hardening
- ❑ **Lateral displacements perpendicular to the load direction** following the lowest embedding stiffness as impact of the orthotropic material profile (Fig. b)

VISUAL INSPECTION AND INTERPRETATION

Changes of the wooden texture

Beneath the dowel:

- ❑ *Inferior areas of crushed wood-cells parallel to the grain* and
- ❑ *Continuous shear and tensile failure* at the zone of sharp redirection of the flow of fibers (usually no bending or tensile failure)
- ❑ Single or double-sided *tensile failure parallel to the grain* and gapping perpendicular to the grain
- ❑ *Densification of wood perpendicular to the grain* with strains up to at least 50%
- ❑ *Delamination of the outer veneer layers* is observable for larger dowel displacements, reducing the effective length for embedment



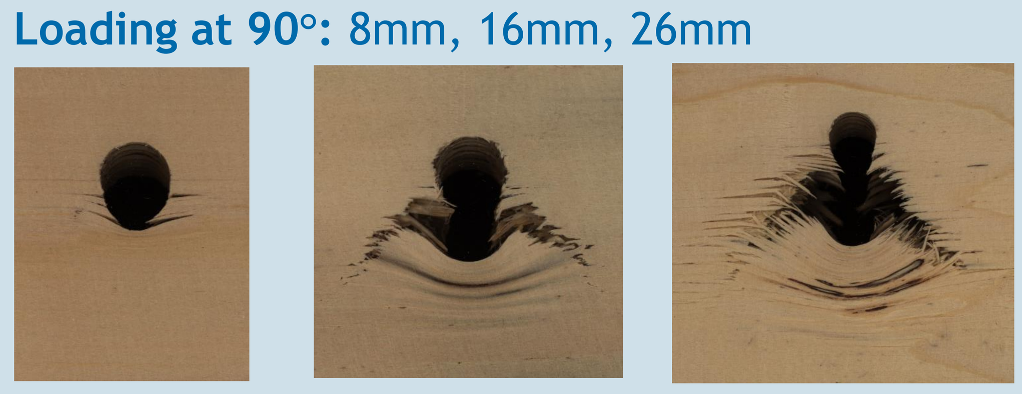
History of crack formation

Loading at 0°: 8mm, 16mm, 26mm

Loading at 30°: 8mm, 16mm, 26mm

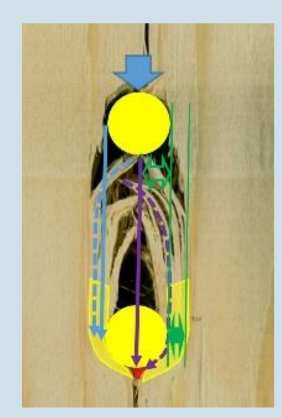
Loading at 60°: 8mm, 16mm, 26mm

Loading at 90°: 8mm, 16mm, 26mm



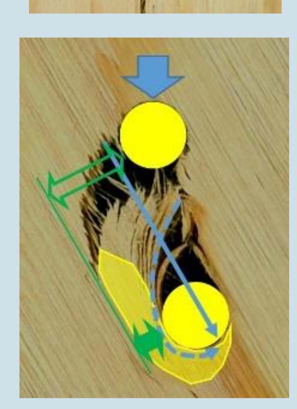
Note: Constrained loading, Φ-12mm

Interpretation of the loading mechanism



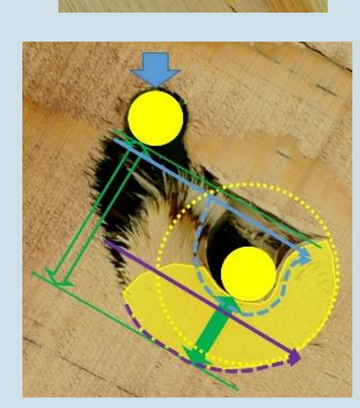
Loading at 0° (parallel to the grain)

- ❑ *ONLY very first load transfer by compression parallel to the grain*
- ❑ Consequent symmetrical flow of fibers around the dowel head (fluid dynamics)
- ❑ Lateral compression and sliding friction
- ❑ Impact of gapping beneath the dowel



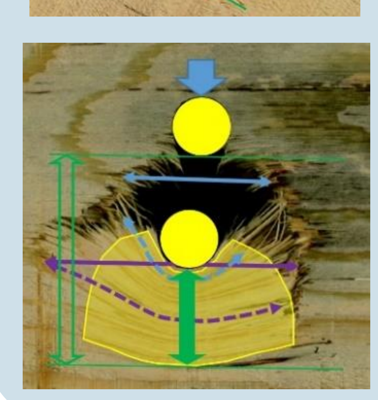
Loading at 30°

- ❑ *Decreased stiffness in line with increased initial loading perpendicular to the grain*
- ❑ *Lateral displacement due to single-side formation of a layer of densified wood*
- ❑ *Rope effect and single sided tensile failure due to bending and wrapping of fibers*



Loading at 60°

- ❑ *Fictitious increase of the dowel diameter by increased bending and wrapping of fibers around the dowel head*
- ❑ Heavy lateral displacements in the case of unconstrained test configuration



Loading at 90°

- ❑ *Fictitious increase of the dowel diameter by a load distribution beam (l ≈ 4x Φ)*
- ❑ Double sided tensile failure due to the rope effect, little asymmetry due to inhomogeneities

CHALLENGE FOR NUMERICAL MODELLING

Features for structural assessment:

- ❑ Large displacements, inducing rope effect and tensile failure parallel to the fibre
- ❑ High strains, typical for compression perpendicular to the grain
- ❑ Superposition of several cracking mechanisms (tensile and shear failure)
- ❑ Friction between singles layers
- ❑ Extensions: Impact of moisture, temperature and creep. Variation of orthotropic material profiles due to growth irregularities like knots...,

Transfer to practice:

- ❑ Strategies for numerical modelling:
  - ✓ Lattice model: uncomplicated implementation
  - ✓ 2D-element: necessary upgrade for high strain formulation
  - ✓ 3D-model: effective length of embedment
- ❑ Model validation also by intermediate load stages
- ❑ Generation of input data for simplified structural sub-modelling

References:
M. Schweigler, T.K. Bader, G. Hochreiner, G. Unger, J. Eberhardsteiner, Load-to-grain angle dependence of the embedment behavior of dowel-type fasteners in laminated veneer lumber, submitted to Construction and Building Materials (2016)