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Experiments on the load-displacement behavior of dowel-type steel to timber connections

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Motivation

DOWEL-TYPE CONNECTIONS

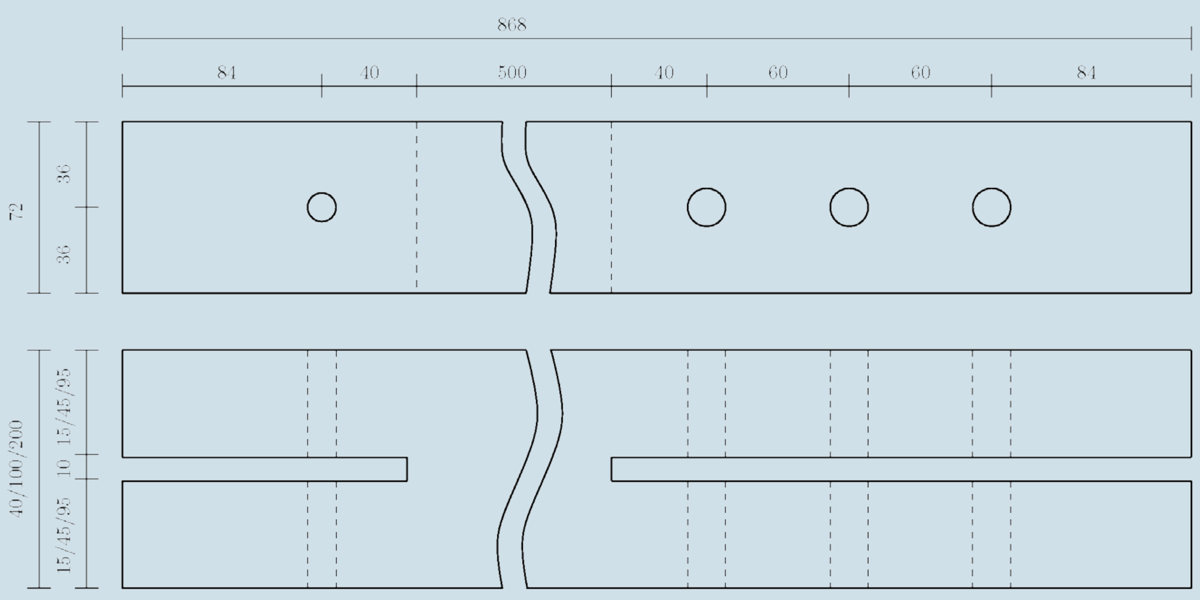
Dowel-type connections are commonly used in structural timber engineering. In the current code generation, e.g. EC5 [1], strength and stiffness design is partially derived from experiments, mechanic needs are not always satisfied. Simulations improve the predictability of connections and are easily adaptable to complex situations (e.g. variation of geometry, or in multi-dowel connections). Still, experiments are needed for validation of the simulations tools.

The experiments focus on the detailed description of the loading-behavior of single dowel-type timber connections. For practical purpose in structural engineering, strength and stiffness of the connections are of high interest. Attention is also drawn on a reliable definition and description of the Serviceability Limit State (SLS). Up to the SLS, deformations must be reversible, plastic deformations in the dowels are therefore not allowed (danger of fatigue).

TEST PROGRAM

The wood in use was Norway spruce, sampled for knot-free regions so that only clear wood was tested. Density ranged from 330 to 510 kg/m³. The specimens showed widths of 40, 100, and 200 m respectively, which were chosen such that all common load bearing mechanisms with and without formation of plastic hinges were covered. All tests were performed with the load applied parallel to fiber direction and a single 12 mm dowel. A total number of 78 tests were performed.

Parameters varied included density, geometry (width, length), dowel roughness (engrailed, sanded), and loading rate. Un- and reloading cycles were performed at various load stages. Some of the specimens were reinforced with clamps to prevent premature cracking.



Methods & Test Results

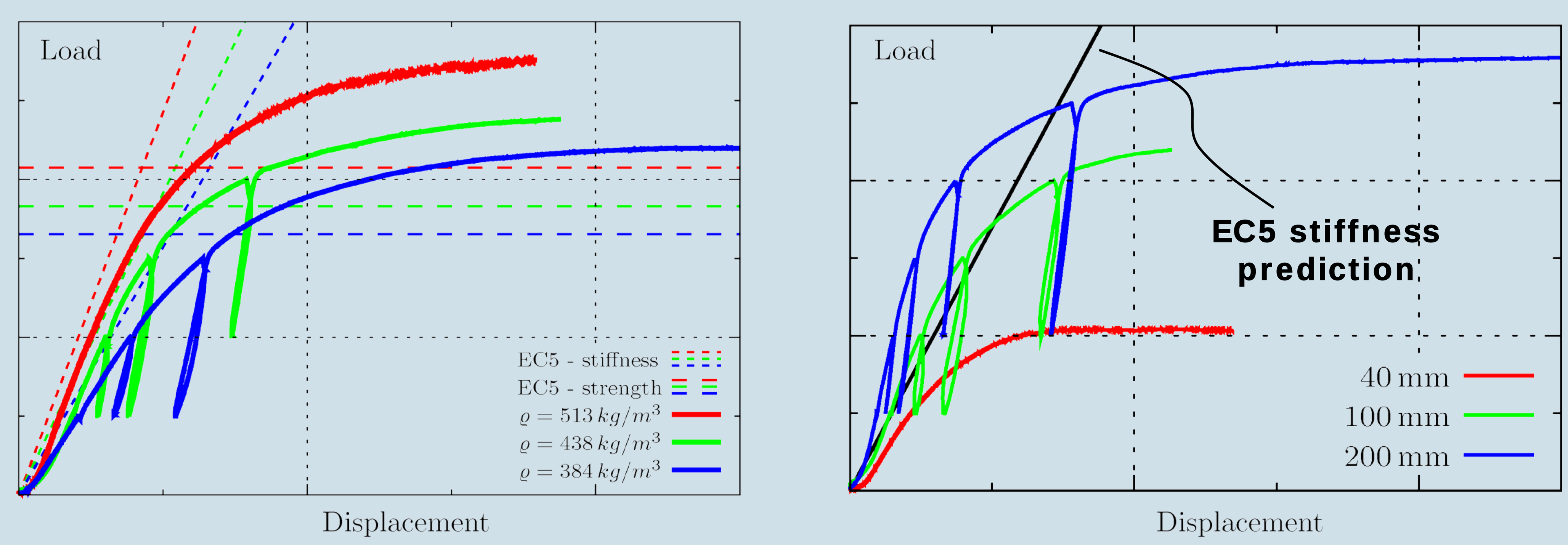
TEST SETUP

Tests were carried out at the Laboratory for Macroscopic Material Testing (IMWS). Tension tests were performed where loads were applied displacement driven, a small number of specimens was loaded under compression.

In addition to force and machine displacement, several additional displacements were measured by means of transducers: relative displacement between steel plate and wood, stiffness of the wood in longitudinal direction, relative displacement of the dowels' ends.

The large variety of individual measurements provides valuable information when comparing experiments to simulations.

COMPARISON TO DESIGN METHODS



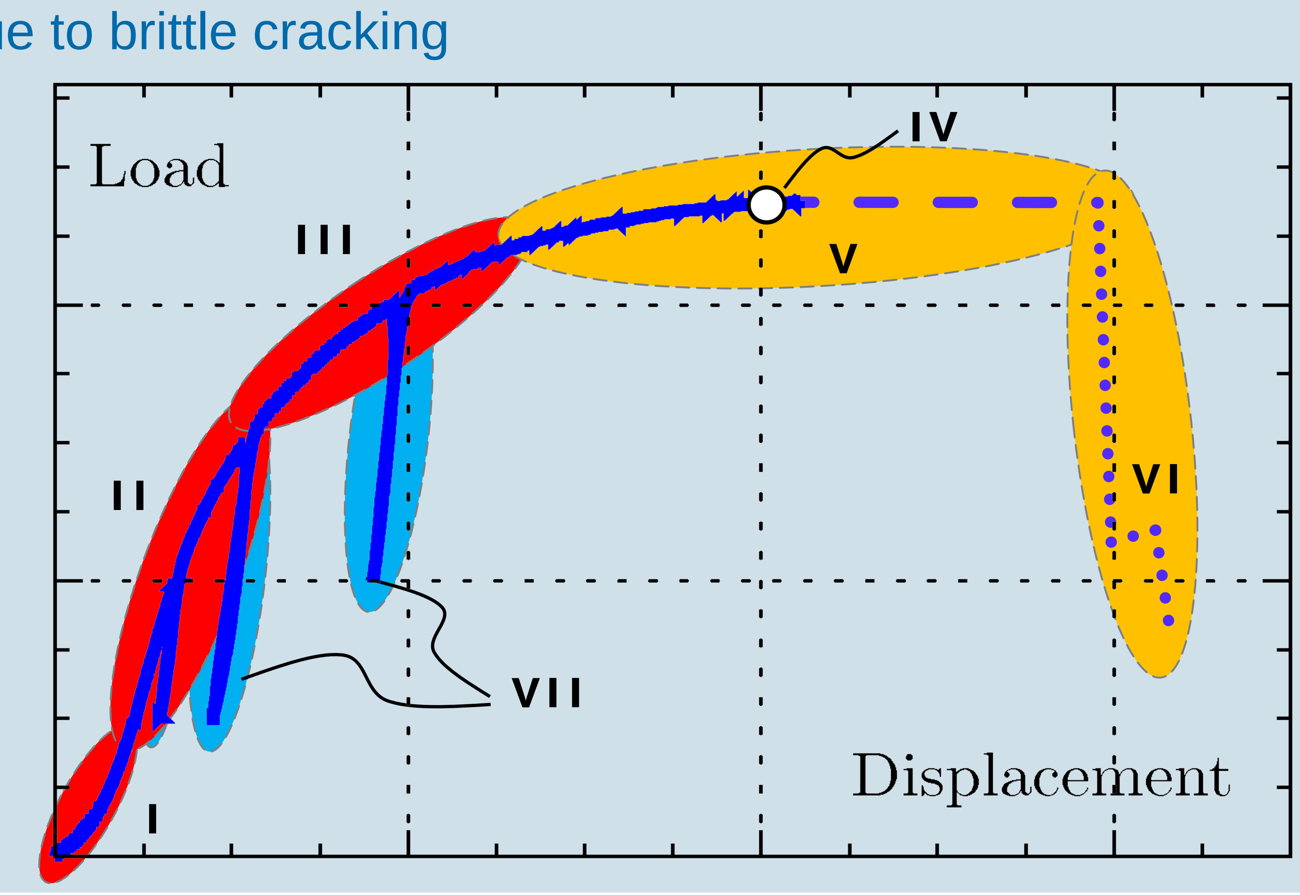
Design strength and stiffness according to EC5 showed good agreement for 100 mm wide specimens with a single plastic hinge (left), regardless respective wood density. Stiffness determination according to the EC5-procedure resulted in an over-/ underestimation of stiffness for 40/200 mm wide specimens (right). This is due to the fact that width of the connection and (plastic) failure mode are considered when determining stiffness.

Results & Outcome

LOADING BEHAVIOR

The loading behavior of dowel-type connections is separated into several stages:

- I: Consolidation: establishment of load transfer (compliant interface)
- II: Maximum stiffness: linear loading phase
- III: Decrease of stiffness: yielding of wood, eventual plastic hinge(s) in the dowel
- IV: Maximum load: dependent on wood strength, friction, reinforcement
- V: Ductile loading plateau: influenced by friction, density, reinforcement
- VI: Failure: load drop due to brittle cracking
- VII: Un-/Reloading path



Typical load-displacement curve for a standard specimen showing individual loading stages

OUTCOME

In the current standard for design of wood structures, mechanical basics are not always satisfied, e.g. width and failure mode of the connection do not influence design values for stiffness. The separation of the loading course into separate stages allows to identify mechanical processes.

The results of the experiments will be used in the improvement of the simulation tool for dowel-type connections. With the help of simulations, insight into the processes can be gained. Parameter identification and parametric studies can be performed more easily than with experiments only, especially for multi-dowel connections where high forces are applied.

Together with the simulations, the Serviceability Limit State can be identified more easily. Experiments allow the definition on a global scale (e.g. stiffness, maximum non-recoverable displacements), simulations give evidence on internal stresses and plastic zones in the dowel and wood.

References:
[1] EN 1995-1-1:2006: Design of Timber Structures - Common rules and rules for buildings

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