TU WIEN imws
INSTITUTE FOR MECHANICS OF MATERIALS AND STRUCTURES

DEPARTMENT OF APPLIED MECHANICS AND MECHATRONICS
KAMaM

Investigating various influences on the embedment strength and stiffness of wood

M. Dorn, K. Hofstetter, V. Nohajová, and J. Eberhardsteiner

Motivation

EMBEDMENT TESTS

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, namely embedment strength tests.

For this work, embedment strength tests were performed according to the European standard EN383 [2] and the US-standard ASTM D5764 [3] respectively. The test procedures differ distinctively: cracking is better prohibited in the European-style tests while loading is distributed more uniformly in the US-style tests.

The experiments aimed at a proper mechanical description of the loading behavior according to the different testing conditions and variation of different influencing properties.

TEST PROGRAM

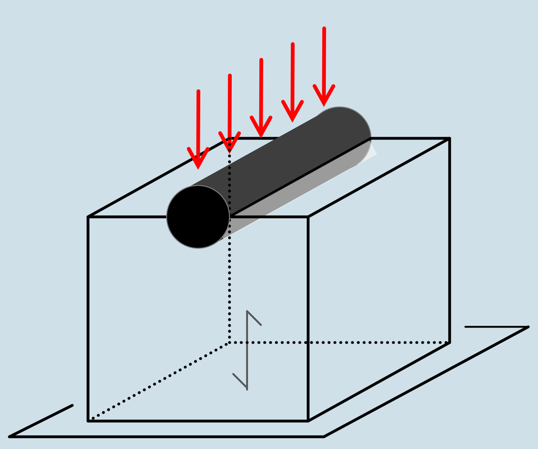
All specimens were prepared according to the European standard. Some of the specimens were then cut into halves to produce US-style specimens. The bore-hole surface of these specimens was scanned by means of a texture measurement device to obtain the waviness and roughness of the bore hole surfaces.

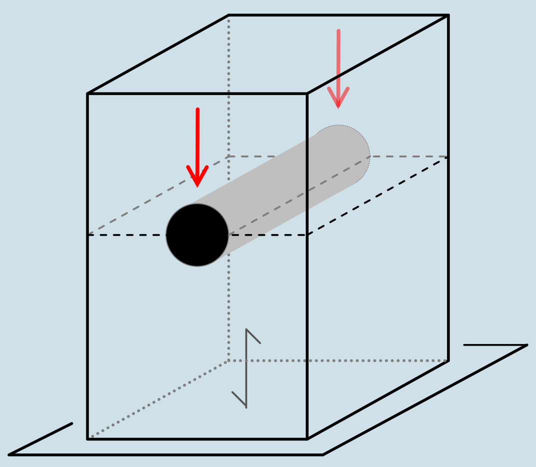
The test specimens varied in wood density (~310-510 kg/m³), geometry (width and height), embedment length (length of wood-dowel contact: 2/4/8/16 d), dowel surface roughness (roughened dowels), and wood surface roughness (different drilling tools). Additionally, the effects of reinforcement by screws was studied.

Loads were applied displacement driven as well as load driven. The test procedure included un- and reloading cycles at different load stages. Stiffness properties are of great interest for structural analysis of buildings, and the different loading behavior of first loading and reloading cycles is not negligible.

Methods & Test Results

US- vs. EUROPEAN-STYLE TESTS





ASTM D5764

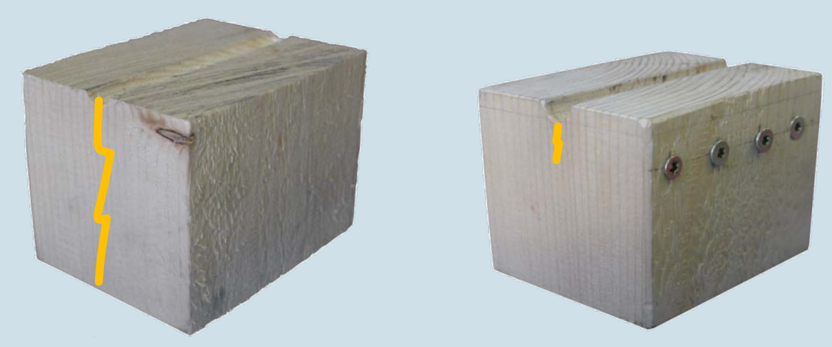
Only the lower half of the dowel is surrounded by wood. Load is then applied uniformly distributed along the length of the dowel which shall guarantee even loading of the bolt-hole.

EN 383

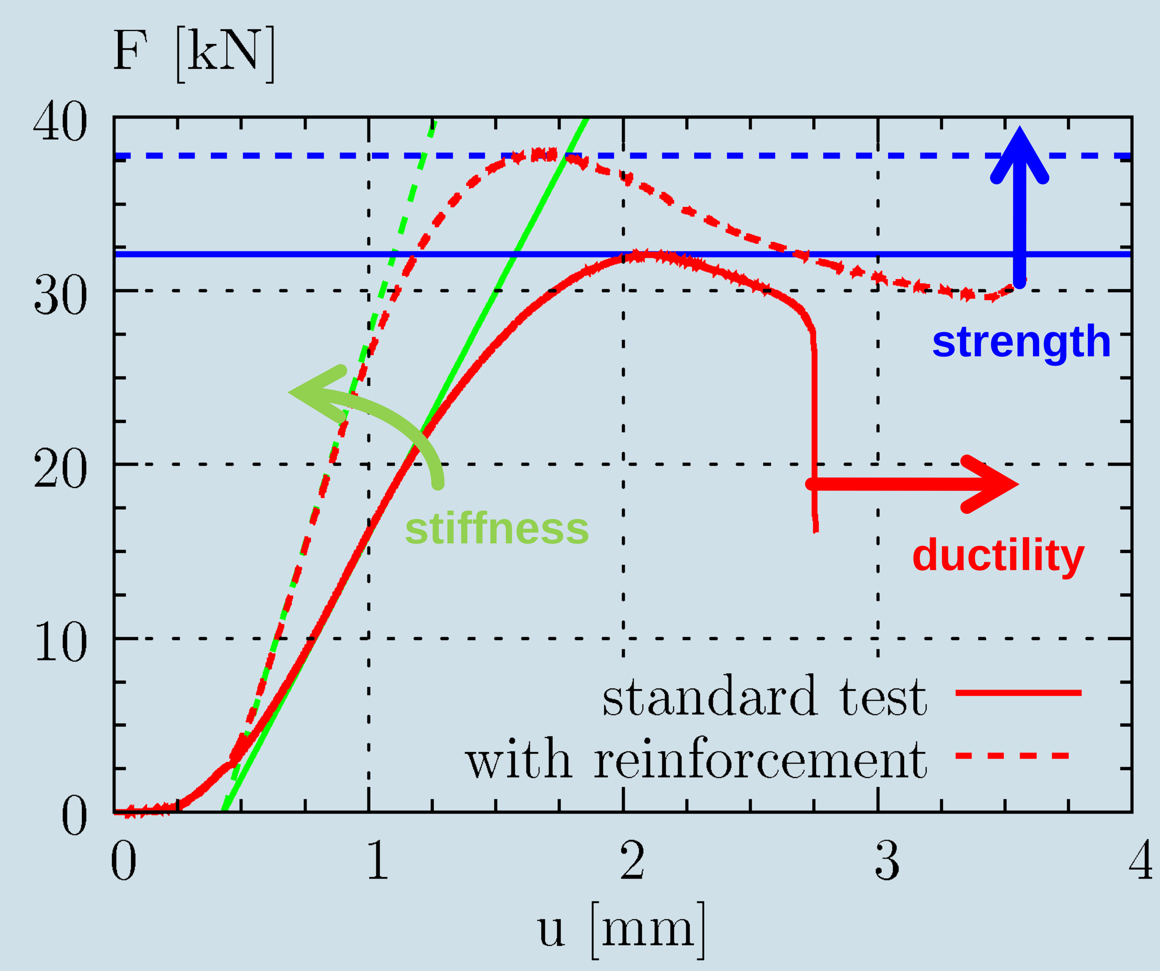
The dowel is pressed into the full cross section. The surrounding wood increases resistance against the formation of lateral tension cracks. The load is applied at the ends of the dowel (dowel bending).

INFLUENCE OF REINFORCEMENT

Screws drilled into the wood take over lateral tension forces so that the integrity of the structures is kept intact. The tests have shown that stiffness and ultimate load level are increased significantly. Crack formation is influenced, higher displacements are possible before final failure occurs.



Standard (left) and reinforced (right) specimens with typical crack pattern: the screws stops crack growth and allow for continued ductile loading



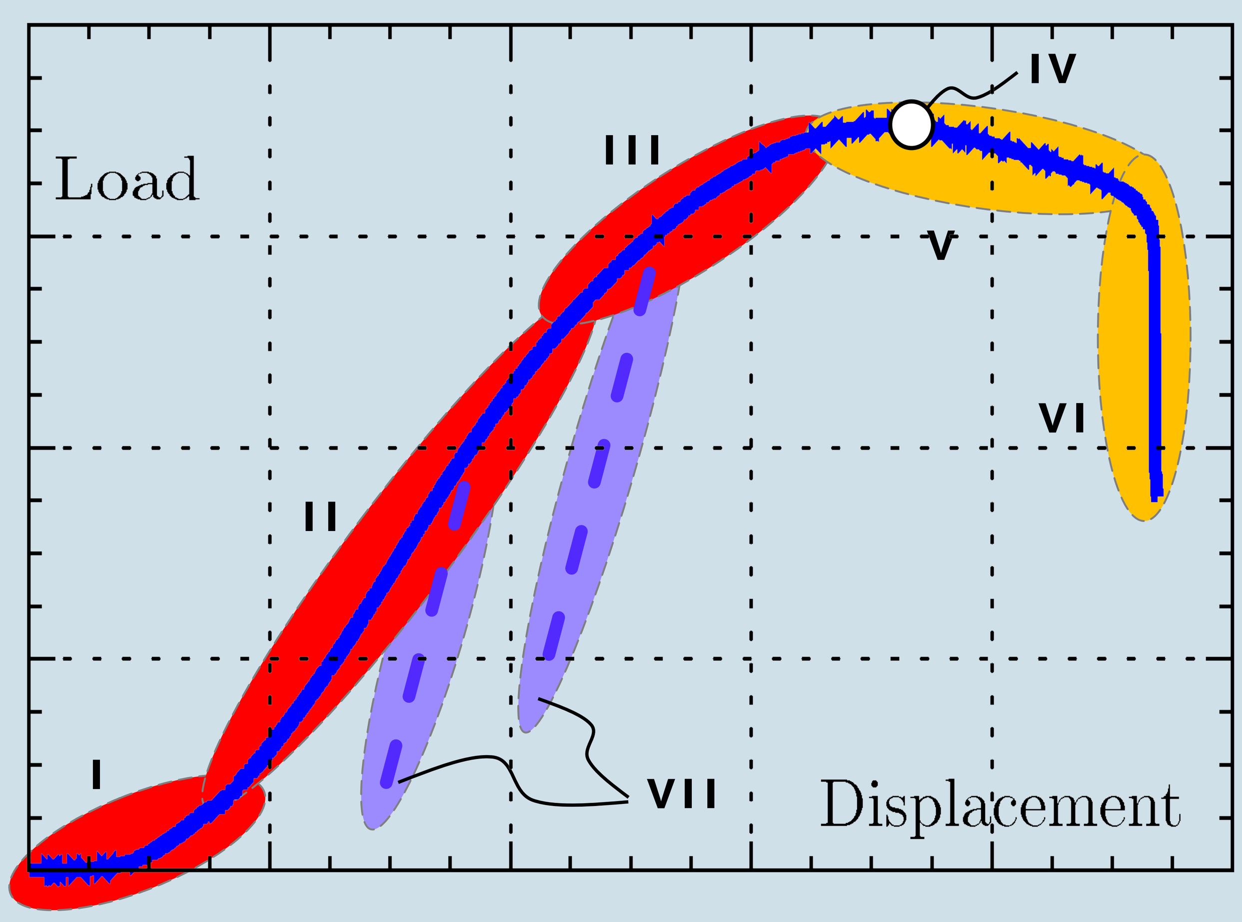
Load-displacement diagram for standard and reinforced specimens: typical changes in stiffness, strength, and ductility

Results & Outcome

LOADING BEHAVIOR

The loading behavior of embedment tests 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
- 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 US-style specimen showing individual loading stages (un- and reloading cycles where not performed during the test)

OUTCOME

In the current standards for design of wood structures, basic mechanical requirements are not always satisfied, e.g. design values for stiffness of connections are not influenced by the width of the connections. Additionally, many formulae are based on experiments, e.g. strength design is estimated by values for embedment strength instead of compressive strength. A proper differentiation between individual loading stages and a sufficient description thereof are essential to gain insight in the process of load distribution under dowel-type fasteners.

In the current design practice, there are no limitations for maximum allowable displacements before cracking and brittle failure occurs. This work finally aims at developing criteria for maximum allowable displacements so that secure ductile loading can be guaranteed.

Further focus is set on the contact behavior between dowel and wood. The initial consolidation does influence loading behavior but reliable studies are not available.

References:

[1] EN 1995-1-1:2006: Design of Timber Structures - Common rules and rules for buildings
[2] EN 383:2007: Timber Structures – Test Methods – Determination of embedment strength and foundation modulus for dowel-type fasteners
[3] ASTM D5764:2002: Standard tests for evaluating dowel-bearing strength of wood and wood-based products

28th Danubia-Adria-Symposium on Advances in Experimental Mechanics
28 September – 1 October 2011, Siófok, Hungary
Poster Number 106