EXPERIMENTAL AND NUMERICAL INVESTIGATION OF TIMBER STRUCTURES FOR THE VALIDATION OF AN ORTHOTROPIC PLASTICITY MODEL

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1. Introduction

Although wood is used as a favourite building material among concrete and steel, the mechanical behaviour was not scientifically investigated yet as one would expect. To be able to perform more realistic simulations of timber structures by means of modern numerical simulation methods like the Finite Element Method (FEM), a suitable constitutive material model is required. Such a material model was developed by Mackenzie-Helnwein in [1] for clear spruce wood and was extended by Fleischmann [2] considering the influence of knots and the deviation of the fibre direction around the knots on the strength properties. Further an implementation of the material model in a Finite Element software was done. For the validation of the material model numerical simulations of wooden structures using FEM and comparison of the obtained results with those of corresponding experiments were done for two test series. The results of these tests will be presented in this contribution.

2. Constitutive Material Model

The orthotropic single-surface plasticity model by Mackenzie-Helnwein [1] regarding non-associated hardening and softening laws (see Fig. 2) based on a comprehensive series of biaxial tests on clear spruce wood, performed by Eberhardsteiner [3]. The principal material directions are shown in Fig. 1. Further experiments on wooden specimens with selected knots for the determination of the material parameters of real boards and the adaptation of the material model was done by Fleischmann [1].

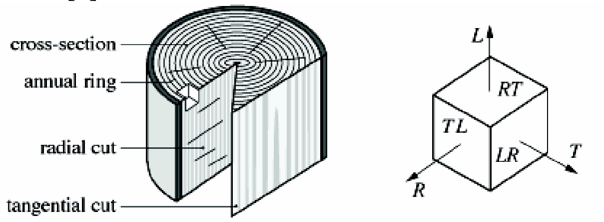

Fig. 1: Section of a stem, principal material directions

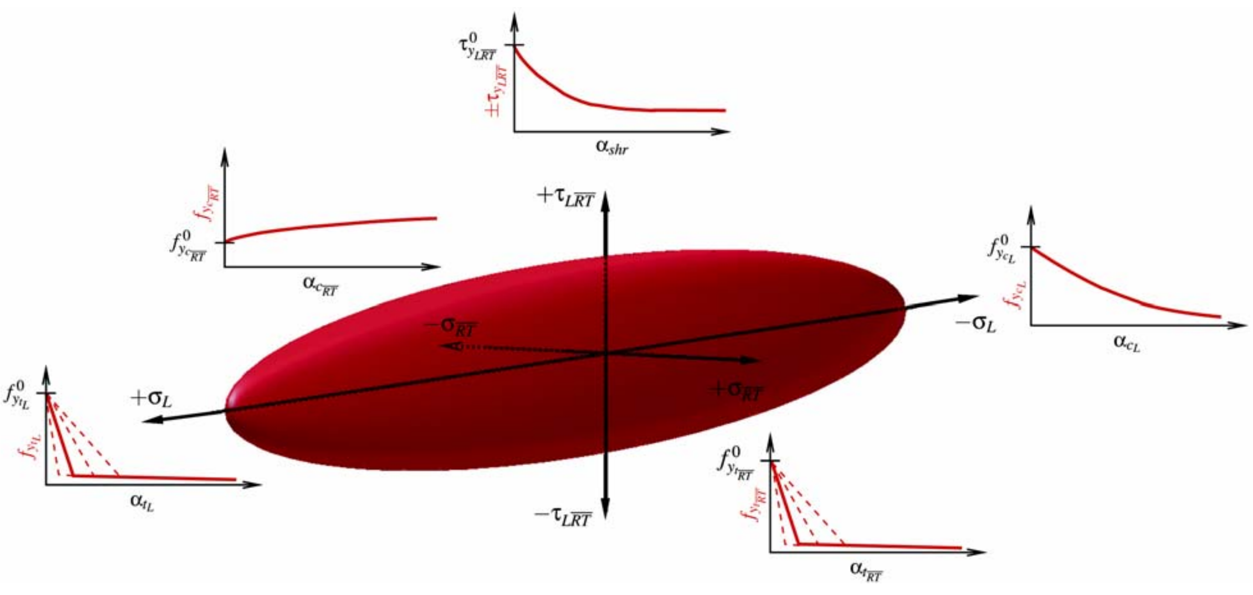

Fig. 2: Elliptical yield surface by Tsai & Wu [4] and evolution laws for hardening and softening, respectively.

3. Example 1: Beam with a Circular Opening

To predict the ultimate load of structures characterised by a brittle failure mechanism, gluelam beams with three different sizes of circular openings were chosen. Each configuration consists of three beams, loaded with a single force (deformation controlled) in the middle of the beam. The openings are situated approximately in the quarter points of the span width of the beams. They have diameters of d = 0.2h, 0.3h, 0.4h, respectively (dimensions of the beam: length x height (h) x width: 4.00 x 0.45 x 0.12 m). Fig. 4 shows one configuration of the nine experiments. In Fig. 5 the load-displacement diagram for series 04 (d = 0.4h) is given. The ultimate load, predicted with a finite element simulation using the proposed material model fits well to the data obtained by the experiments.

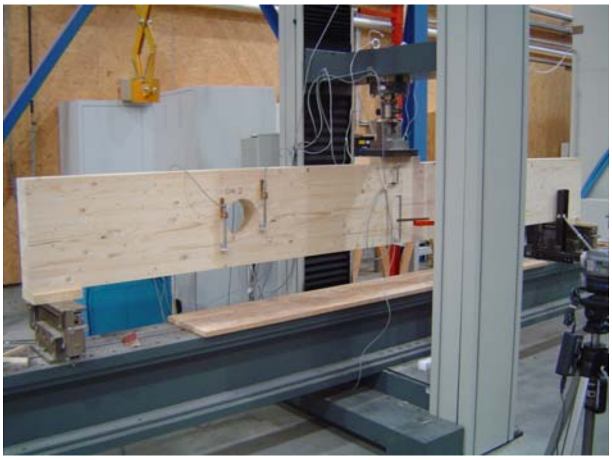

Fig. 4: Configuration of the experiment (specimen 04.2)

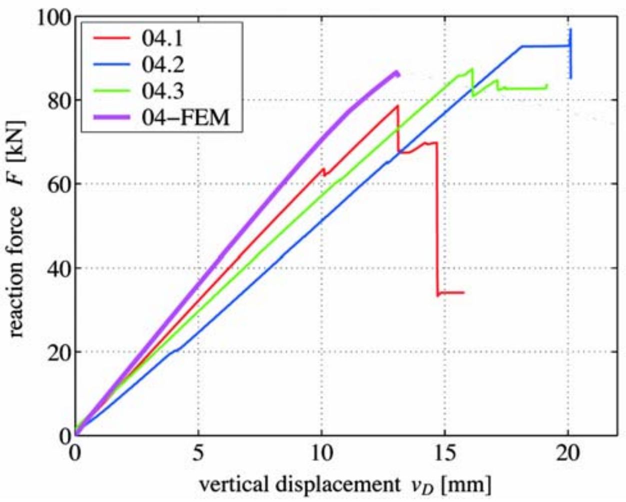

Fig. 5: Load-Displacement diagram (series 04)

4. Example 2: Truss

For the second test series a structure with a ductile failure mechanism was chosen to investigate the plastic behaviour of spruce wood for dominating loading situations perpendicular to grain. A simple truss consisting of three truss members was manufactured three times. The joints were done by step joints. All tests were performed by a displacement controlled vertical movement of the tie. Fig. 6 shows one configuration of the experiments and in Fig. 7 the corresponding load-displacement diagram for the tie is drawn. Except of the common scatter of material properties in timber engineering, the result of the prediction of the ultimate load is satisfying.

Fig. 6: Configuration of the experiment (specimen 03.3)

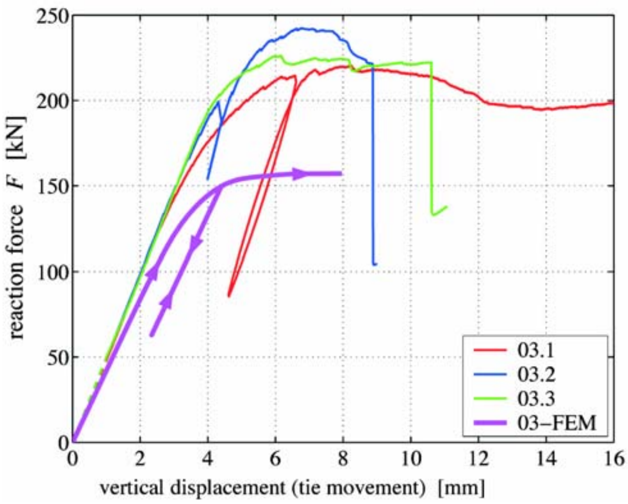

Fig. 7: Load-Displacement diagram (series 03)

5. References

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3. J. Eberhardsteiner: *Mechanisches Verhalten von Fichtenholz – Experimentelle Bestimmung der biaxialen Festigkeitseigenschaften*, Springer-Verlag, 2002.
4. S.W. Tsai, E.M. Wu: *A General Theory of Strength for Anisotropic Materials*, Journal of Composite Materials, 5:58-80, 1971.