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Modelling and Numerical Analysis of Wooden Structures

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ABSTRACT

The numerical simulation of wooden structures using the finite element method (FEM) requires close-to-reality material models, suitable element technologies, path-following algorithms and an adequate consideration of wood inhomogeneities to answer static-constructional questions reliably.

A moisture depending three-dimensional elastic-plastic material model for wood of Norway Spruce is presented and evaluated with respect to experimental tests. The material formulation bases on a multi-surface plasticity model, which considers anisotropic post-failure behaviour. An exponential function defines hardening due to compression perpendicular to fibres. The disproportionate increase of strength owing to densification at large plastic compressive strains is taken into account additionally.

To consider tensile and shear failure as localised failure modes and to yield discontinuous displacement fields, a formulation for cohesive elements, so-called interface elements, are developed. This type of elements permits the discrete modelling of tension and shear cracks. The interface-elements contain an anisotropic material model for wood, which couples the failure modes determined experimentally above all. The definition of the model-behaviour is made by the parameters of tensile strength transverse to grain, shear strength in two directions of the plane orthogonal to grain and failure energies of three fracture modes. The function of the material model and its derivative - the algorithmic material tangent - are continuously in order to guarantee a robust path-following algorithm. Thus, the material model supports the simulation of damage scenarios caused by not-monotonous loading conditions.

Aspects of solving non-linear FEM equations using NEWTON-RAPHSON-method and the NEWMARK time integration procedure are discussed. Numerical examples underline the necessity for a C_1-continious force-deformation-relationship. Beyond, it is shown that a path-following disregarding dynamic effects can lead to misinterpretations of the numerical results in the post-collapse behaviour. Therefore, a procedure is presented, which permits at the one hand the static and time-independent structural analysis within static stable ranges, at the other hand the transient response in the case of failure even due to quasi-static loading. The quality of the models is shown on the basis of comparisons between the results of simulations and experimental investigations.