A review of computational methods to describe the strength and failure behavior of wood and wood-based products and their embedment into a holistic design approach

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Increased use of wood has led to complex timber constructions and new types of wood-based products. In simulations, however, mainly simplified models are used to describe this material with strongly varying properties and a complex mechanical behavior. Wood, as a naturally-grown material, exhibits a highly anisotropic and inhomogeneous material structure, with a complex wood fiber distribution influenced by randomly occurring knots. Thus, for the prediction of effective strength properties of wood, advanced computational tools are required, which are able to predict as well as consider multidimensional strength information at different scales of observation.

Therefore, we developed a multi-surface failure criterion [1], which is able to describe brittle and ductile failure mechanisms of wood, based on simulations on several length scales. Combined with a geometric reconstruction algorithm for knots [2], such a tool can be used to determine effective strength properties of knot sections. Due to the highly orthotropic failure behavior of wood and the strong variations of material directions close to knots, this task is very challenging.

The extended finite element method is a powerful technique that allows for a very realistic description of strength-governing processes. Nevertheless, its complexity and high computational effort prevent widespread use in the engineering field, and it is limited by frequently occurring geometric incompatibility issues. Plastic limit analysis and elastic limit approaches [3,4], however, show good predictive performance compared with the extended finite element method, coupled with excellent efficiency and stability. In this study, it is found that together, the latter two approaches are able to enclose the experimentally-obtained failure regions for clear wood almost perfectly, while also delivering new insights with respect to the ductile failure potential of wood and wood-based products. Furthermore, the – in this field – relatively new phase field method may represent a solution to often encountered problems with respect to stability, reliability, and description accuracy.

Finally, strength properties of wooden boards are condensed into so-called strength profiles. By applying this approach to a large set of wooden boards, probabilistic material models can be developed and used in simulations of wood-based products [5]. In such a framework, sensitivity analysis and robust design optimization becomes possible and could lay the basis for a more holistic and, thus, also efficient design of timber structures.

References

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