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Advanced concepts for modelling failure and transport processes in wood and wood-based products

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ABSTRACT

The field of engineered timber construction has seen a significant upsurge in recent years. This surge is attributed to increased focus on sustainability and ecology, improved quality and availability of innovative timber products, and the reliable integration of these products into complex structural frameworks. Despite this growth, assessing and modelling the mechanical performance of timber constructions pose challenges due to the variability of construction elements, connection materials, and specialised components. This has been pre-dominantly addressed through experimental determination of mechanical properties, which proves time-consuming and offers limited scalability.

A potential solution lies in experimental programs with numerical simulations, which can generate abundant mechanical data about a tested component. Not restricted by measurement methods used in experiments, numerical models provide detailed insights into deformation, strain, and stress states. Given a trustworthy numerical model, extensive parameter studies can be conducted to generate a comprehensive database for further development of guidelines and standards. Furthermore, for large components like glued laminated timber beams or cross-laminated timber panels, numerical simulations are much more cost-effective than equivalent experimental tests.

However, the benefits of numerical simulations hinge on the creation of models that realistically depict the mechanical behaviour of complex timber components. Challenges include the need for reliable material parameters, the variability of naturally grown wood, and the modelling of the material's orthotropic behaviour. Also, material nonlinearities, like quasi-brittle failure mechanisms, need to be considered, necessitating suitable numerical methods and adequate input material parameters. Notably, validating simulation tools based on selected experiments is essential to assess prediction quality and increase confidence in simulation results.

Although a general simulation tool capable of addressing all these challenges does not currently exist, scientific activity in this domain is increasing with promising developments worldwide. This presentation aims to illustrate the potential future of numerical simulation tools in selected areas of relevance for timber construction: the numerical modelling of moisture transport processes in wood and quasi-brittle failure mechanisms in timber components. The presentation introduces a model that can describe moisture transport processes under and over the fibre saturation point of wood [1, 2]. An engineering approach to determining moisture gradients in cross-sections of wood, depending on the relative humidity of the environment, is presented, along with an extension of this simulation concept to predict moisture-induced cracking [3]. Additionally, a model predicting

the bending strengths of glued laminated timber beams is discussed [4], highlighting its use in investigating the controversial size effect in glued laminated timber beams [5]. Finally, a numerical concept, the phase-field method [6], is introduced. This method could, for the first time, be capable of describing complex failure mechanisms in wood in a physically based and stable manner [7]. The presentation concludes with representative examples where numerical simulations could be applied.

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