A numerical approach towards the understanding of climate-induced fracture in oak wood

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ABSTRACT

Historical cabinet doors occasionally show damage caused by fluctuations in the ambient relative humidity and temperature. The oak substrates experience shrinkage, shrinkage cracks and warping, which are effects that require challenging conservation treatments [6, 2]. For a safe and sustainable preservation of the object, insight in the underlying climate-induced failure mechanisms is essential. Accordingly, this work presents a sequentially-coupled finite element model that accurately can simulate climate-induced damage in oak wood. This is done through accounting for moisture hysteresis and discrete fracture by, respectively, combining the approaches presented in [3, 1]. A systematic study demonstrates that the simulations provide realistic predictions of climate-induced damage development in oak wood. The model is used to analyse the deformation and failure behaviour of a cabinet door subjected to single and multiple stepwise decreasing relative humidity profiles, from 60% to 20%. In correspondence with the experimental results presented in [4], the numerical results illustrate that restrained hygral shrinkage observed in the historical cabinet doors can be a potential source of damage. The presence of cleated ends introduces restrained hygral shrinkage due to a directional difference in the coefficients of hygroscopic expansion of structural components forming a coherent connection. It is further shown that for new oak wood, which has a tensile strength of 21 N/mm^2 [5], no damage occurs in the cabinet doors. Conversely, for historical oak wood having a tensile strength of 6 or 12 N/mm^2 [5] the cabinet doors experience a macroscopic failure crack in the oak wood substrate, accompanied by the formation of substantial micro-damage. For animal glue joints with a relatively low strength, t^u_{glue}=0.5t^u_{oak}, failure occurs in the glue joint, without the generation of micro-damage in the oak wood.

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