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# Asymptotic homogenization of the effective hygro-elastic response of oak based on microscopic images

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Oak is a strong and durable wood that has been widely used throughout the centuries for creating art objects, such as decorated furniture and panel paintings. However, oak wood is sensitive to climate variations, which may accelerate long-term aging and degradation processes. This work investigates the relationship between the ultrastructural features of oak and the hygro-mechanical properties of the growth rings, in order to study the response of historical oak wood objects under indoor climate variations. The asymptotic homogenization method is used for the multi-scale analysis of the wood response at the nano-scale and meso-scale [1]. The nano-scale description is based on a cellulose nano-fibril model, which consists of a core of crystalline and dislocated cellulose in the series form [2], which together are embedded in a non-crystalline cellulose matrix. The non-crystalline layer is embedded in a randomly distributed matrix of hemicellulose and lignin [3]. The moisture dependency of the material is attributed to the hydrophilic phases, including the non-crystalline matrix of cellulose, hemicellulose, and lignin. The nano-scale unit cell is homogenized for various moisture contents based on the mechanical properties of the constituents, thereby using the specific adsorption isotherms of the different phases [4]. The hygro-elastic properties of the cell walls are estimated for different values of the microfibril angle and crystallinity index. The meso-scale model is based on representative volume elements of the growth rings, as created by converting microscopic images to a finite element model for the wood material. Stained thin-cut sections of an oak sample are scanned using a digital automated microscope to prepare high resolution images. The effective hygro-elastic properties of the growth rings are presented as a function of the density and moisture content of the samples. The results are compared with experimental data taken from the literature, illustrating a good agreement.

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