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A quantitative study on residual stresses in wood induced by aqueous adhesives

Falk K. Wittel*, Philippe Grönquist, Markus Rüggeberg, Hans J. Herrmann

ETH Zurich, Institute for Building Materials, Stefano-Franscini Platz 3, CH-8093 Zurich,
fwittel@ethz.ch, www.ifb.ethz.ch

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Modern structural applications of timber rely on durable adhesive connections. Delaminations reduce the loading capacity of structures such as gluelam and the aesthetic appearance. For predicting the onset and growth of delaminations, it is essential to consider changes in the ambient climate and the hygro-mechanical response of all wood components [1]. Additionally, their history needs to be captured to consider cyclic stress build-up from contributions of mechano-sorption. Residual stresses from bonding with aqueous adhesives like PRF or MUF are up to date neglected, due to their difficult quantification.

Residual stresses will arise, if dimensional changes induced by the locally introduced moisture of the adhesives are blocked by the hardened adhesive. When adhesives are applied on the wood surface, local swelling results with high moisture contents close to the surface. Under this condition, adhesives harden and block relative movements of adherents. When the moisture in the adherents equilibrates, locally swollen regions shrink and, thus, introduce residual stresses. It is, therefore, a competition between moisture transport inside the bulk wood and the curing kinematics of the adhesive, which inevitable leads to the development of residual stresses when bonding with aqueous adhesives.

A purely computational approach suffers from unfounded assumptions on the wood-adhesive interaction during curing and its evolution. We, therefore, propose a combined experimental – numerical approach, wherein two wood strips are bonded to a bi-layer with orthogonal grain directions. After reaching the prescribed compression time, the deflection behaviour of the bilayers is measured during equilibration. This procedure is repeated for spruce and beech as well as MUF and PRF adhesive systems. Resulting residual stresses are calculated using a moisture-dependent rheological model for wood and adhesives [2]. The model consists of three layers of the configuration wood-adhesive-wood. We define two relevant parameters: (a) the moisture transmission coefficient from adhesive to wood, and (b) the curing time, from whereon tangential stresses can build up in the adhesive. We inversely quantify the two parameters using the experimentally determined deflection evolution of the bilayer samples. Finally, we calculate residual stresses inside the bilayers and provide estimates for gluelam structures by applying the calibrated model.

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