Numerical sensitivity study of moisture induced stress levels in glulam cross sections

M. Schiere[†*], S. Franke[††], B. Franke[†‡], A. Müller[‡‡]

[†]Bern University of Applied Sciences, Institute for Timber Construction, Structures and Architecture, Solothurnstrasse 102, CH-Biel, marcusjacob.schiere@bfh.ch
[††]Bern University of Applied Sciences, S. Franke, steffen.franke@bfh.ch
[†‡]Bern University of Applied Sciences, B. Franke, bettina.franke@bfh.ch
[‡‡]Bern University of Applied Sciences, A. Müller, andreas.mueller@bfh.ch

Wood is a hygroscopic material of which dimension and strength change as moisture content varies. Expected moisture content of timber during service life is an important parameter for structural engineers to ensure structural safety and design extra measures if necessary. Internal stresses generated during moisture content changes are capable of developing internal and surface cracks in a glulam cross section. Earlier findings on moisture induced stresses have not found their way yet towards a practical application in today's building standards. Neither are methods available for structural engineers or building planners to include reduction of load capacity perpendicular to the grain in their daily design or building maintenance planning. This knowledge could be used in the design of large span timber structures of which glulam is a main structural component.

After study of diffusion speed and moisture content distribution in larger glulam cross sections, both through experiments and numerical simulations [1], research continued towards calculation of moisture induced stress distributions. A simpler 1D-model [2] was rebuilt along with a 2D-FEM model [3]. In the 2D-FEM model, similar equations were used as in the 1D-model, except that distinction between radial and transverse material parameters was possible instead of the need to average them over the glulam's cross section. The development of the stresses is calculated by using the derivative of the total strain ε_t to time. The total strain is a summation of the reversible contribution of the hygro-mechanic strains ε_s and the elastic strains ε_E and the time-dependent components ε_{ms} and ε_c better known as the mechano-sorptive and the creep strains, respectively:

$$\dot{\varepsilon_t} = \dot{\varepsilon_s} + \dot{\varepsilon_E} + \dot{\varepsilon_{ms}} + \dot{\varepsilon_c} \tag{1}$$

Good agreement was found between the stresses calculated through the 1D-model, the 2D-model, and those obtained from experiments on a 90 mm wide cross section [4]. The numerical models were subsequently used to perform sensitivity studies of generated stress levels to cross section size, aspect ratio, and ambient climate variations, see Figure 1. All studies were performed with glulam beams composed of identical boards. Slight horizontal variations in layup reduced potential stress levels more than 10 %. The relation between load duration and stress level could also be observed with the performed simulations. The numerical models can be used to further research critical moisture load scenarios, board layups, and possibilities to reduce generated stresses through reinforcements or application of surface coatings. This can lead to improved glulam products and subsequently keep on encouraging application of timber in modern architecture.

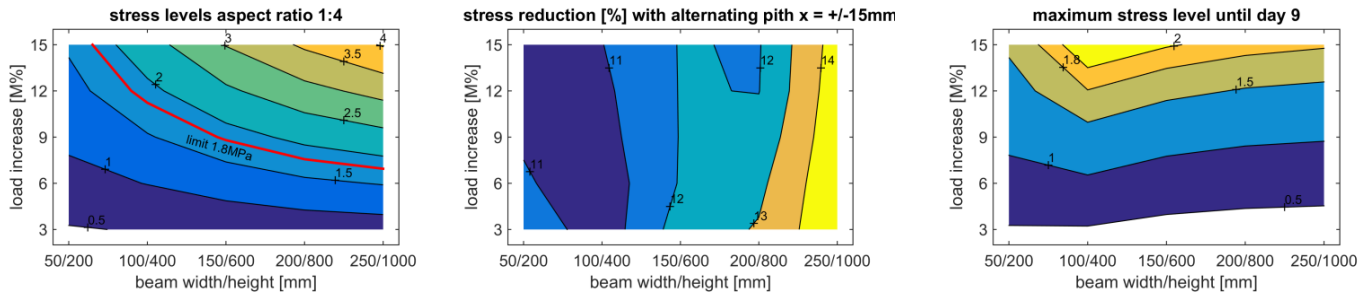

Figure 1: Study of effect cross section size, board layup, and load variation on absolute stress limits

References

[1] S. Franke, B. Franke, A. Müller, M. Schiere: Long-term behaviour of moisture content in timber constructions – relation to service classes, INTER conference proceedings, Graz, Austria, 2015.

[2] M. Häglund: Varying moisture content and eigen-stresses in timber elements, Wood Materials Science Engineering, Vol. 3, pp. 38–45, 2008

[3] V. Angst-Nicollier: Moisture induced stresses in glulam - effect of cross section geometry and screw reinforcement, PhD thesis, NTNU Trondheim, Norway, Thesis number 2012:139, 2012

[4] J. Jönsson: Internal stresses in the cross-grain direction in glulam induced by climate variations, Holzforschung, Vol. 58, pp. 154–159, 2004