NUMERICAL MODELING OF WOOD-ADHESIVE BOND-LINE IN MODE II FOR SPRUCE WOOD GLUED BY VARIOUS ADHESIVES

Václav Sebera, Jaka Gašper Pečnik, Boris Azinovič, Miha Kramar

ABSTRACT

Bond-line creates an interface between two glued surfaces and, therefore, it brings additional complexity into the mechanical behavior of glued components, especially around the bond-line region, because an adhesive has a very different response to a mechanical stress than wood. From this perspective, the bond-line influences the total mechanical response of glued components by both its cohesive and adhesive behavior at wood-adhesive boundary. For timber constructions, there are many various adhesives one can use and each of them has a different mechanical characteristics, advantages and disadvantages. The goal of this work was to create a numerical finite element models applicable for analysis of fracture problems in mode II. The models were developed for the adhesives that are often applied in timber constructions and wooden materials. The FE models include 2D geometry of the bond line and cohesive law fitted on the outputs of the experimental measurement. The experimental data for the developing numerical models were obtained using 3point end-notched flexure (3ENF) tests with the compliance-based beam method (CBBM) coupled with the digital image correlation to be able to obtain displacement slip needed for the development of the FE models. Furthermore, within the FE analysis, wood was modeled as orthotropic material including both elastic and plastic regions of deformation. The FE models were developed in Ansys computational system. The specific objectives of the work were as follows: 1) to create cohesive zone models based on experimental data; 2) to develop parametric 2D and 3D model of the bond-line reflecting experimental data; 3) to analyze the influence of friction coefficient on resulting force-displacement outputs; and 4) to analyze plastic imprint into the specimens for Norway spruce and the influence of the fiber angle inclination.Implementation of cohesive law models of wood-adhesive system into the FE analysis was successful. The FE analysis provided the force-deflection response that was validated by the experiment work. The FE model showed that influence of friction on simulated force may be up to 5% of the maximal force, which is not a negligible effect. The imprint of the load head into specimen is substantial if span-to-height ratio is below 17. The influence of the fiber angle with respect to a longitudinal axis is rather high, i.e. angle of 14° means 30% reduction of maximal force.

REFERENCES

de Moura, M. F. S. F., Silva, M. A. L., de Morais, A. B., & Morais, J. J. L. (2006). Equivalent crack based mode II fracture characterization of wood. *Engineering Fracture Mechanics, 73*(8), 978–993.

Méité, M., F. Dubois, O. Pop, and J. Absi. “Mixed Mode Fracture Properties Characterization for Wood by Digital Images Correlation and Finite Element Method Coupling.” *Engineering Fracture Mechanics* 105 (June 2013): 86–100.

J. Milch, J. Tippner, V. Sebera, M. Brabec: Determination of the elasto-plastic material characteristics of Norway spruce and European beech wood by experimental and numerical analyses. *Holzforschung* 70 (2016), 1081-1092.

Silva, M. A. L., de Moura, M. F. S. F., & Morais, J. J. L. (2006). Numerical analysis of the ENF test for mode II wood fracture. *Composites Part A: Applied Science and Manufacturing, 37*(9), 1334–1344.

Silva, M. A. L., Morais, J. J. L., de Moura, M. F. S. F., & Lousada, J. L. (2007). Mode II wood fracture characterization using the ELS test. *Engineering Fracture Mechanics*, *74*(14), 2133–2147.

Silva, F. G. A., Morais, J. J. L., Dourado, N., Xavier, J., Pereira, F. A. M., & De Moura, M. F. S. F. (2014). Determination of cohesive laws in wood bonded joints under mode II loading using the ENF test. *International Journal of Adhesion and Adhesives*, *51*, 54–61.

Xavier, J., Morais, J., Dourado, N., & De Moura, M. F. S. F. (2011). Measurement of mode I and mode II fracture properties of wood-bonded joints. *Journal of Adhesion Science and Technology*, *25*(20), 2881–2895.

Yoshihara, H. (2001). Influence of span/depth ratio on the measurement of mode II fracture toughness of wood by end-notched flexure test, 8–12.

Yoshihara, H., & Ohta, M. (2000). Measurement of mode II fracture toughness of wood by the end-notched flexure test. *Journal of Wood Science*, *46*, 273–278.