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PREDICTION OF EFFECTIVE STIFFNESS PROPERTIES OF WOODEN LIGHTWEIGHT PANELS BY MEANS OF NUMERICAL SIMULATIONS

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ABSTRACT

The need for increased efficiency, the aim of reducing useless weight, and the decreasing availability as well as increased prices of raw materials have led to the development of wooden lightweight panels. Nowadays the panels are generally used for furniture and door panels, but also applications for walls or ceilings are conceivable.

Recently a new kind of wooden lightweight panel named DendroLight was developed by the Dendro Light Holzwerkstoffe GmbH, which is an Austrian wood-working company. DendroLight is a three-layered panel. The thin outer layers consist of solid wood or particle board and provide basic stiffness to the panel. The middle layer is made up of small cells with webs inclined by an angle of 45°. The arrangement of the cells is such that they face upwards and downwards alternately, so that the webs cross each other at right angles. The mechanical characterization and optimization of the panel requires investigation of a multitude of panel designs with different materials, different overall thicknesses, and different ratios of the layer thicknesses. In order to reduce the numbers of prototype tests, numerical simulations were performed.

These simulations were based on the Unit Cell Method formulated for a plane medium [1, 2, 3, 4]. This method allows for determination of homogenized macroscopic stiffness properties of materials with periodic microstructures. The Unit Cell, which is the basic repetitive unit of the microstructure, is subjected to periodic boundary conditions. Depending on the stiffness component of interest, either a macroscopic unit strain state or a macroscopic unit curvature state is applied to the Unit Cell. The local stress and strain fields resulting from these macroscopic loadings are determined by means of the Finite

Element Method. The generalized stress resultants are equal to the homogenized stiffness properties of the panel. In particular, effective in-plane stiffnesses and bending stiffnesses are obtained. Under consideration of the panel thickness, six elastic constants can be derived therefrom: the in-plane moduli of elasticity in tension parallel and perpendicular to the principal orientation of the middle layer cells, $E_{\|,t}$ and $E_{\perp,t}$, the in-plane shear modulus G_s, the moduli of elasticity in bending with respect to the latter orientations, $E_{\|,b}$ and $E_{\perp,b}$, and the shear modulus in torsion G_t. The results of the computations show that the influence of the middle layer on the overall stiffness of the panel is mainly controlled by the main material orientation of the two outer layers. If the load is acting in direction of higher stiffness within the outer panels, the middle layer contributes only a small part of the overall stiffness. If the load, on the other hand, is acting in direction of lower stiffness within the outer layers, the modulus of elasticity is mainly contributed by the middle layer.

For the purpose of model validation, several panel samples were produced by hand and tested in tension. The experimental results show a good agreement with corresponding stiffness predictions by the model. More comprehensive test series, allowing for a complete validation of the model and for an improvement of prediction accuracy, are planned for the future.

REFERENCES

[1] J.C. Michel, H. Moulinec and P. Suquet. “Effective properties of composite materials with periodic microstructure: a computational approach”. *Computer methods in applied mechanics and engineering.*, Vol. **172**, 109–143, 1999.

[2] D.H. Pahr. “Linear and Non-linear Homogenization using FEM”. *ILSB-Report.*, 2004.

[3] J. Hohe. “A direct homogenisation approach for determination of the stiffness matrix for microheterogeneous plates with application to sandwich panels”. *Composites: Part B.*, Vol. **34**, 615–626, 2003.

[4] D.H. Pahr and F.G. Rammerstorfer. “Buckling of Honeycomb Sandwiches: Periodic Finite Element Considerations”. *Computer Modeling in Engineering & Sciences.*, Vol. **1(1)**, 101–113, 2004.