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MODELING ANISOTROPIC ELASTICITY OF MULTI-LAYER ENGINEERED WOOD PRODUCTS

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ABSTRACT

Strand- and veneer-based engineered wood products are widely used in the field of structural engineering. Besides laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL), which are mainly used for beams and columns, the oriented strand board (OSB) is the main representative for structural panels. OSB consists of slender wood strands which are bonded together with an adhesive, where the strands are arranged in a three-layer assembly. Despite considerable effort to improve the mechanical properties of OSB, its application range is more or less limited to roof, wall, and floor sheetings due to moderate board stiffness and strength.

The present research project aims at the development of a multi-layer strand board with improved mechanical properties by using large-area veneer strands. Their uniform, consistent, and predictable properties render these strands a top quality raw material for the panels called veneer strand boards (VSB), which are suitable for load bearing applications. In order to optimize the new wood product, the effects of strand characteristics and panel assembly features on the mechanical performance of the multi-layer panels has to be revealed. So far, the influence of strand quality, strand shape, strand size, and strand orientation as well as the effect of layer characteristics on the macroscopic mechanical behavior has been investigated by experiments for the most part. Experimental work allows for identification of the parameters with a dominant effect on the mechanical properties, but it does not reveal the underlying mechanics.

Herein, a model is presented which combines sound mechanical theory and accompanying experiments for parameter identification and model validation. The model is intended to enhance insight into the mechanical behavior of the panels and, thus, to contribute to a better understanding of the influence of the (micro-) structural characteristics mentioned above. This makes the model a valuable tool for engineering design and for optimization of the mechanical performance of veneer strand boards. Since a multi-layer panel exhibits three scales of observations, namely strand material – single-layer – multi-layer panel, a multiscale approach is required. In particular, two

modeling steps have to be established to connect the three hierarchical levels. First, a homogeneous single-layer panel is modeled by means of continuum micromechanics [1]. This method is based on a matrix-inclusion problem at the microscale, which can be solved on the basis of the work of Eshelby [2]. This model approach has already been successfully applied to solid wood [3]. The continuum micromechanics model is capable to estimate the entire stiffness tensor of heterogeneous materials and, thus, provides all nine independent material constants of an orthotropic single-layer panel. Thereby, the estimated stiffness tensor is a function of the stiffness tensors of the microstructural components, their volume fractions, their shape as well as their orientation. In the second homogenization step, the multi-layer panel is modeled by means of lamination theory. The stiffness tensor from the first model step, the stacking sequence, the orientation of the principal material directions of the single layers, and the density variation across the panel thickness are input variables here. On the whole, this model enables to predict the macroscopic mechanical performance of strand based panels on the basis of microscopic mechanical and morphological characteristics. It constitutes a novel and promising design tool in the field of engineered wood products.

The identification of model parameters and the validation of the model are based on experiments. For determination of the mechanical properties of the strands, large-dimension timber of Norway spruce was sliced into veneers and then cut into veneer strands with dimensions of 1 mm thickness, 25 mm width and 210 mm length. This procedure ensured uniform strand geometry and strand size with little divergence. Uniaxial tension tests in longitudinal direction of the strands provided the stiffness and strength in this direction and delivered some insight into the mechanical properties of the used raw material. Experimental stiffness data, density, and wood quality parameters were combined in order to estimate the entire stiffness tensor for the raw material with a micromechanics model for solid wood [3]. For the purpose of validation of the first homogenization step, single-layer panels were produced. The single-layer panels differed in strand orientation, mean density, and wood quality of the used strand material and showed a uniform density across the thickness. In order to validate the second model step, multi-layer veneer strand boards were produced with different layer assemblies and distinctive vertical density profiles. The single-layer panels were tested in tension and shear whereas the multi-layer panels were tested in bending and tension, providing the experimental data for model validation. On the whole, a good agreement of experimental data and corresponding model prediction was observed. This demonstrates the capability of the model for stiffness estimation of strand based engineered wood products on the basis of microstructural features and renders it a powerful tool for parameter studies and product optimization.

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