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THE INFLUENCE OF THE LAMELLA WIDTH ON THE STIFFNESS OF THE LIGNIN-CELLULOSE BASED PANELS

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ABSTRACT

The paper presents a theoretical study based on FEM analysis compared with the experimental data obtained after subjecting a lignin- cellulose based panel, made of mixed hardwood (beech and maple) to an uniformly distributed load, during a bending stress. The panel is supposed to support on four fulcrums and it is subjected to a static load. How is the stiffness of the panel been influenced by the variation of the lamella width? There is a question the present paper will answer using the theoretical and experimental data .

Keywords: Finite Element Method, beech and maple wood, bending stress, stiffness.

1. INTRODUCTION

The study in this paper referes to the anisotropic panels made of small sized solid wood lamellas, finger jointed on length and edge jointed on width, using urea-formaldehyde adhesives. Wood is an anisotropic–orthotropic material due to its elastical properties which depend of a great number of factors as wood species, density, wood moisture and its temperature, position of annual rings and direction of the grains against the strain position and also on the time in which the force is applied.

The panels must fulfil the following main conditions in order to be used as raw material for fields as construction, transport and furniture manufacturing: a good resistance, stability and stiffnes. The stiffness is a good indicator of the panels' deformations in case of bending strains. The stiffness is expressed by the following equation:

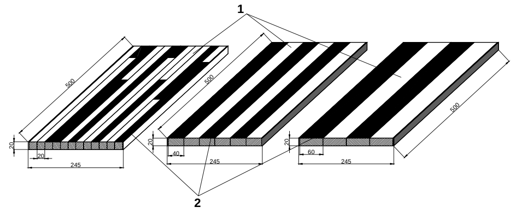
$$\mathbf{S} = \frac{\Delta \mathbf{P}}{\Delta \mathbf{f}}, \text{N/mm} \qquad (1)$$

In which $\Delta \mathbf{P}$ represents the variation of the force applied to the panel and $\Delta \mathbf{f}$ represents the variation of the deflection.

The theoretical analysis with FEM applied to the panels’ bending strain intends to find the tendency of the phenomena and the experimental data will confirm the conclusions obtained with the theoretical model. Of course the theoretical analysis will not take into consideration all the real data, because the wood is not a homogeneous material, but it is an anisotropic- orthotropic material.

2. SAMPLES, THEORETICAL METHOD AND RESULTS

The samples used for the theoretical method are finger jointed panels of 500x250 mm format, made of beech wood mixed with maple wood, as seen in figure 1 and 2. The standard panel to compare the results was the same construction of panel but made only of beech wood lamellas.



a b c

Figure 1. The real model of the panel; 1-beech wood; 2- maple wood; a- lamella width of 20mm, b-lamella width of 40 mm; c- lamella width of 60 mm.

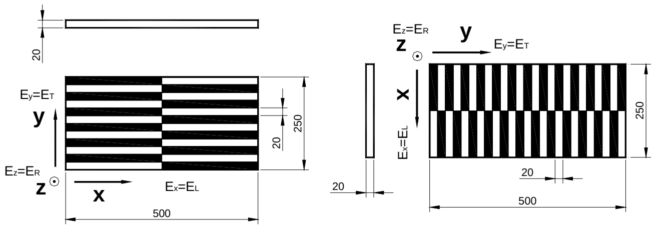


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Figure 2. The theoretical model used for FEM analyse; a – longitudinal structure; b – transversal structure

The panels are considered to be subjected to a static uniformly distributed load, p = $0,355 \cdot 10^{-2}$ N/mm^2, as represented in figure 3. The panel is supposed to supports on four fulcrums ($S_1 \ldots S_4$). The first analysis has not taken into consideration the adhesive layer between the wood lamellas and the interactions at the microscopically level at the interface wood- adhesive. The structures considered in that first case were both longitudinal and transversal ones and the theoretical model have been considered that both species are represented in equal pars into the panel, as seen in figure 4. The FEM analysis has been performed for the lamella widths of: 10 mm, 20 mm, 30 mm, 40 mm, 50 mm and 60 mm.

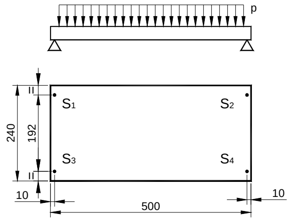

Figure 3. The way the panels were considered to be subjected to the uniformly distributed load

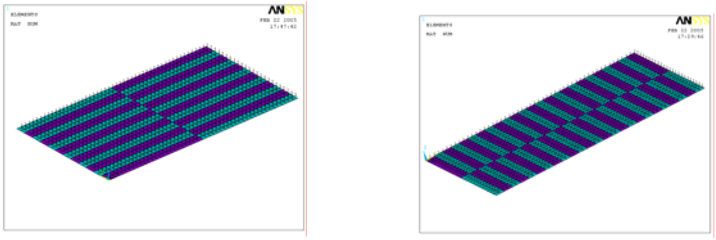

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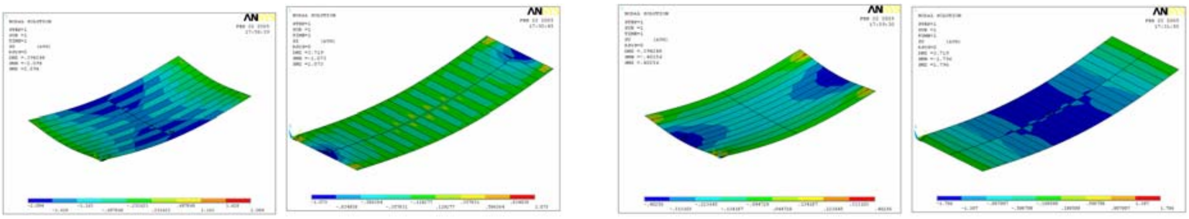
Figure 4. The model generated by the software for FEM analysis; a – longitudinal structure; b – transversal structure;

The stresses (s_x) are distributed for the longitudinal and the transversal structure, as shown in figure 5.



a b c d

Figure 5. The distribution of the stresses in the panels-(s_x) for longitudinal structure; b -(s_x) for transversal structure; c -(s_y) for longitudinal structure; c -(s_y) for transversal structure.

The maximum stresses on „x“ axis are concentrated in the centre of the panel for the longitudinal structure, The „x“ axis is considered that oriented on the direction of the lamellas' length. In this case the maximum stresses in the transversal structure are distributed on a small area of the width panel edge. The stresses are considerable higher for the transversal structure on „y“ axis and they are distributed on a large area in the centre of the panel.

The stresses distribution represents the mirror of the panel deformation. Analysing the deformations obtained through the FEM analysis, the diagram from figure 6 has been obtained. The maximum deflections of the transversal structures are approximately seven times higher than those of the longitudinal structure. The values of the deflections in the first case when the adhesive layer was not considered have shown that there are very small differences between them. On the other hand, considering the adhesive layer we came to the conclusion that the deflection decreases for bigger widths.

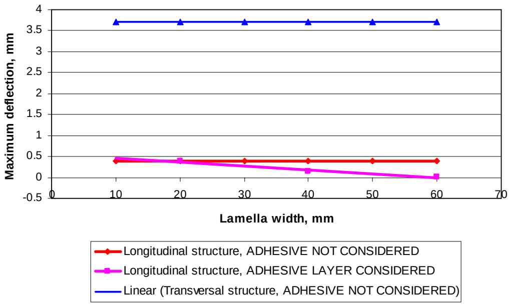


Figure 6. The maximum deflection of the panel for various lamella widths.

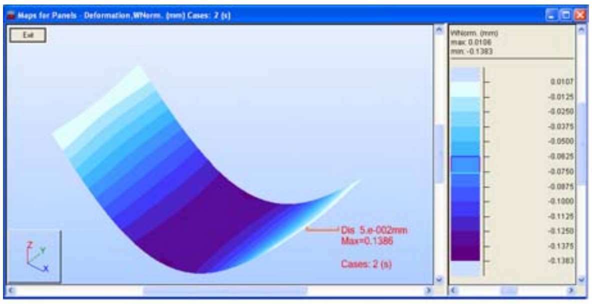


Figure 7. The deformation of the panel in case of considering the adhesive layer.

3. EXPERIMENTAL METHOD AND RESULTS

In order to confirm the theoretical results the panels were experimentally subjected to a static uniformly distributed load, as shown in figure 8. The weights of 1 kg each have been uniformly distributed on the panel surface and the panels’ deflections in the five points indicated in figure 9 have been measured during a period of 25-30 days

Figure 8. The experimental device used to measure the deflection in the five points indicated in figure 8 .

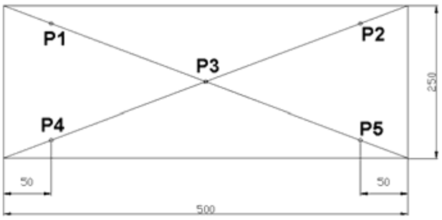


Figure 9. The five points in which the deflection of the panel have been measured.

In order to confirm the theoretical results the panels were experimentally subjected to a static uniformly distributed load, as shown in figure 9. The weights of 1 kg each have been uniformly distributed on the panel surface and the panels’ deflections in the five points indicated in figure 9 have been measured during a period of 25-30 days. The theoretical results have been confirmed because the deflections of the panel experimentally determined were approximately similar with those theoretically determined. In figure 10 are represented the five curves of deflection measured in the five points during the 35 days of the test performance.

In figure 11 it is represented as a comparison the diagram of the deflection values theoretical determined through FEM analysis.

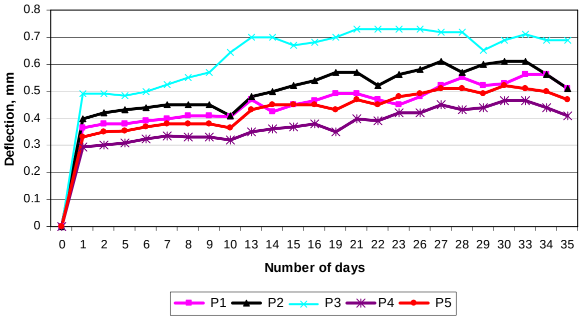


Figure 10. The diagram of the deflection curves measured experimentally in the five points .

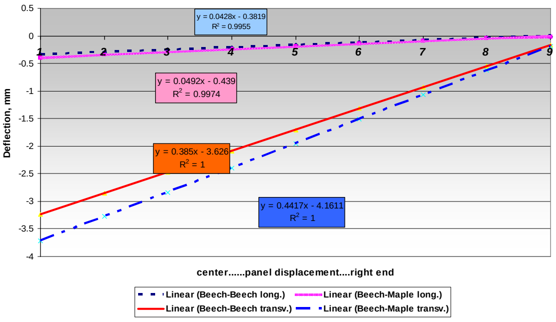


Figure 11. The diagram of the deflection regression functions obtained through the theoretical analysis.

4. CONCLUSIONS

The tendency of the curves represented in the diagrams from figure 12 shows that both in the theoretical and the experimental case the deflection decreases for bigger widths of the component lamellas.

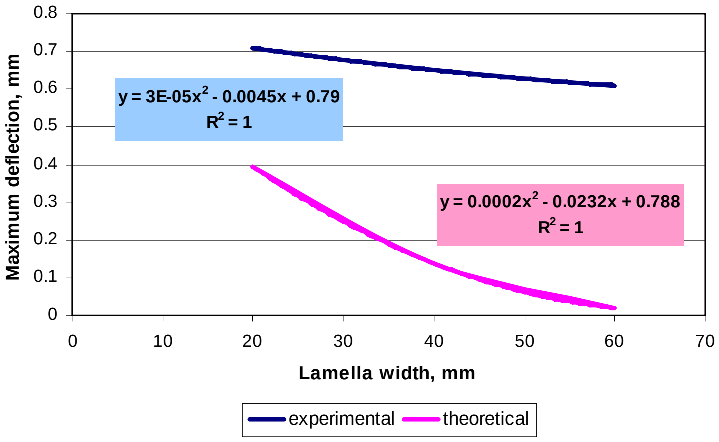


Figure 12. The dependence of the "z" size variation and the relative air humidity, the expression of the deformations for various combinations of hardwood species.

There is a difference between the obtained values in the two cases but they are generated by errors in the theoretical model connected with the following issues: the values of the elastically parameters of the two wood species are considered to be those corresponding to a wood moisture content of 10% and 11% respectively, and the real panels are made of mixed wood having the wood moisture content of 8-9%; the participation of the species included in the panel is considered to be 50% of each, but the real participation is not exactly 50% of each, and also the elastic parameter values are considered to be the average of the parameters of the species included in the panel; the anisotropic-orthotropic features of the wood are not considered in the FEM analysis.

6. REFERENCES

[1] Boieriu C.: Contribution to the Study of the Decorative Finger-Jointed Panels, Made of Hardwood, Used for Interior Arrangement and Furniture , PhD Thesis , Braşov, Romania, 2006.

[2] Zienkiewicz, O.C., - The Finite Element Method, vol I, II, Mcgraw Hill, London, 1991.

[3] Curtu I., Ghelmeziu, N.: Mecanica lemnului şi materialelor pe bază de lemn (Wooden and Wooden Based Material Mechanics), Editura Tehnică Bucureşti, 1984.