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BONDING QUALITY AND BENDING STRENGTH OF LAYERED LIGNOCELLULOSIC MATERIALS INFULENCED BY VENEERS MOISTURE CONTENT

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Abstract

The aim of the research was to analyze the impact of softwood veneer and hardwood thin boards moisture content, on the bonding quality and on bending strength of layered lignocellulosic materials made from these raw materials. The mentioned materials prior to glue bonding were conditioned in different air moisture content to achieve various equilibrium moisture content. The research showed that in the studied range of variability of the parameters used, no significant influence of the changed factors (in this case wood moisture content) on the bending strength and the bonding quality was found. Nevertheless, it should be added, that the moisture content of wood used to create layered composites, can have a significant impact on the parameters of the bonding process, i.e. overheating of the pressed set of wood layers, as well as on the detailed technological guidelines for pressure control in the press as a function of pressing time.

Key words: *wood moisture content, equilibrium moisture content, conditioning, bonding quality, bending, tensile strength, shear strength*

INTRODUCTION

According to Mukudai and Yata (1986), the fundamental mechanism of viscoelastic behaviour of wood under moisture change is the looseness of the interface between the S1 and S2 cell wall layers. Going from the sub-micro- to macro scale, that looseness can lead to decrease the mechanical strength of wood. Moisture content changes have a significant impact in case of composite materials, like wood mechanically enhanced by fiber – reinforced polymers (FRP) (Zhou *et al.* 2015). The macroscopic tests showed that the mechanical properties and fracture behaviour of such composites notably change under various levels of air humidity. The moisture absorbed by such multi – layer system critically determines the mechanical features of the entire system. Kläusler *et al.* (2013) confirmed, that in case of various ambient moisture conditions (5 – 95% relative humidity), the tensile strength and modulus of elasticity of wood bonded with use one component polyurethane or melamine – urea – formaldehyde resin depends linearly. Both mentioned mechanical parameters decreased remarkably with increased relative humidity. In case of plywood production, the moisture content of veneers is counted as a one of most important factor influencing the bonding strength (Demirkir *et al.* 2013). The significance of wood moisture content and ambient relative humidity was investigated by Bomba *et al.* (2014). In the mentioned research it has been confirmed, that in a humid environment,

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the strength of joints created with use PVAc (poly(vinyl acetate)) glue falls below the minimum of the standardized value. The bonding and bond resistance of white oak, sugar maple, aspen, Sitka spruce, southern yellow pine, and ipe have been tested by Frihart *et al.* (2008). The achieved data indicate, that the wood properties greatly influence the internal and/or interfacial stress and thus the durability of the bonded assembly.

The goal of this research was to analyze the impact of softwood veneer and hardwood thin boards moisture content, on the bonding quality and on bending strength of layered lignocellulosic materials made from these raw materials.

MATERIALS AND METHODS

Veneers

The study used pine (*Pinus sylvestris* L.) with a nominal thickness of 3.2 mm, circumferentially cut. The veneers have been obtained from one of the plants, industrially producing the veneers with the thickness as above. The dimensions of the sheets in which it was delivered for testing were approx. 1000 x 1000 mm^2.

The tests were also carried out on samples of oak boards (*Quercus robur* L.) with a nominal thickness of 3 mm and a humidity of approx. 5%. The boards were obtained from the industrial sawing of oak wood on a frame saw.

Glue mass

A glue mass based on an industrial urea – formaldehyde resin was used to bond the composite layers. A hardener was added to the resin in such a way that the curing time of the composite was not longer than 120 seconds at 120°C.

Wood conditioning

In order to prepare the research material to determine the influence of wood moisture on the gluing quality and selected strength properties of lignocellulosic layered composites, the above mentioned raw material, previously formatted to 320 x 320 mm^2 for pine *(Pinus Sylvestris* L.) and 320 x 120 mm^2 for oak *(Quercus* L.), has been conditioned at 20°C in a climatic chamber, which is part of a set of devices for synergistic modification and analysis of the properties of wood materials, in which the air parameters (temperature and humidity) are computer controlled. The set air relative humidity levels were as follow: 10, 35, 64, 75, 92 and 95%. For each of the mentioned humidity levels, sets of pre-samples were prepared, in a number enabling the preparation of not less than 12 samples from each wood species, each humidity variant for each type of test.

The conditioning was conducted to the weight stabilization state, in which the weight difference of a single pre-sample, measured at 24h intervals, was not higher than 1%. For this purpose, 5 sheets of each type of wood were inspected.

The final equilibrium moisture of the conditioned materials was determined by a gravimetric method, using for this purpose 5 samples with dimensions of 50 x 50 mm^2 from each type of wood for each of the applied climates.

Preparation of composites – bonding

After the conditioning process, lignocellulosic composites were made, consisting of 2 layers of coniferous and deciduous wood, respectively, mentioned above, bonded with the mentioned adhesive mass, applied in an amount of 180 g/m^2 per single bonding line, pressed at 120°C for 300 seconds. at a maximum unit pressure of 1.5 MPa.

Bonding quality tests, as well as bending strength during static bending, were carried out in accordance with the methodology described in the following standards: EN 310:1994

and EN 314-1:2007. For each of the above mentioned tests, no less than 12 samples from each wood species variant and a given humidity during the conditioning were used. The glued layered materials were cut into samples according to the above mentioned standards, after which the samples were subjected to conditioning at 20°C / 65% air relative humidity to stabilize the samples weight.

The studies used, among others, an universal testing machine, which is part of a set of devices for synergistic modification and analysis of wood materials properties.

RESULTS AND DISCUSSION

Equilibrium moisture content of conditioned materials

The obtained equilibrium moisture content of conditioned wood materials is shown in fig. 1. As it can be seen from the figure below, in the applied air relative humidity, the equilibrium moisture content of the pine wood varied from 2.2% to 20.4%, and the moisture content of the oak wood varied from 2.6% to 22%. It was found that the moisture content level of oak wood was on average almost 14 percentage points higher than the moisture content of pine wood.

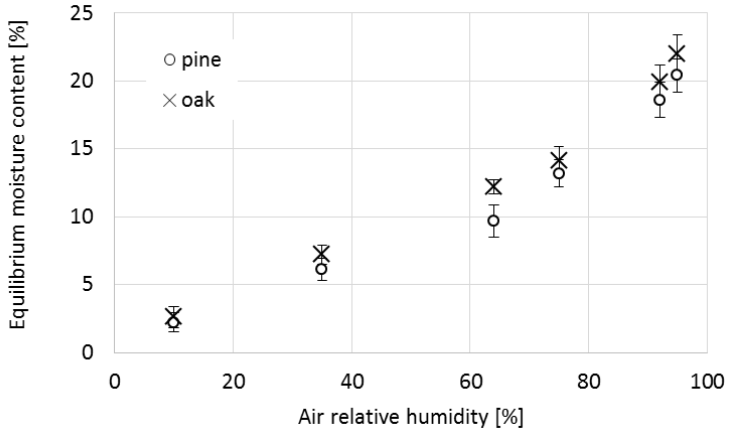

Fig. 1. Equilibrium moisture content of veneers conditioned in variable air relative humidity

Bending strength

The results of the bending test of samples made of wood conditioned before gluing in different humidity conditions are shown in fig. 2. As it can be seen from the data presented, the moisture content of the wood before gluing slightly affects the bending strength of the layered composite made of the mentioned wood. In the case of pine wood, with the increase of its moisture content from 2.2% to 9.7%, there was a slight increase in the bending strength of the layered composites. This increase was from 37 N/mm^2 for moisture content of 2.2% to 44 N/mm^2 for moisture content of 9.7%, and it was the highest value of strength in the tested range of moisture content of wood. With further increase in humidity, the strength slightly decreased to 40 N/mm^2 for 20.4% moisture content. In the case of oak wood, the relationship was similar. However, the hgher values of bending strenght have been obtained for oak wood, in regards to pine wood: maximum, 47 N/mm^2 for moisture content of 12.2% and minimum, 39 N/mm^2 for 2.6% moisture content. It should be added, that in the case of both, pine and oak wood, taking into account

the dispersion of individual results of the bending strength test, around the average values, presented in fig. 2, there is no basis for claiming the statistical significance of the differences of individual average values.

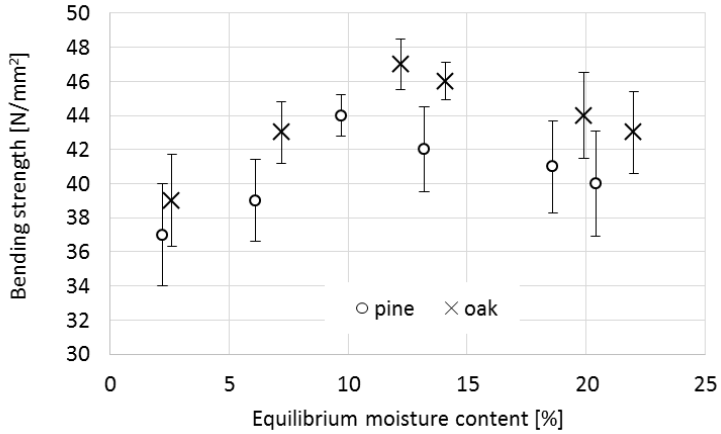

Fig. 2. Bending strength of bonded composites influenced by equilibrium moisture content of veneers

Bonding quality

The results of the tensile shear strength tests of the lignocellulosic composites, made of wood conditioned in different humidity conditions before bonding, are shown in fig. 3. The presented data show that the tensile shear strength of the tested samples increased slightly in the case of samples made of wood with an equilibrium moisture of 9.7% and 12.2% for pine and oak, respectively. The maximum strength values, obtained for these variants, were 4.2 N/mm^2 for pine and 6.9 N/mm^2 for oak. With a further increase in moisture content, a slight decrease in tensile shear strength was noted.

It is worth noting that both, in the case of pine and oak wood, taking into account the dispersion of individual tensile shear strength test results around the mean values presented in fig. 3, there were no statistically significant differences between individual mean values.

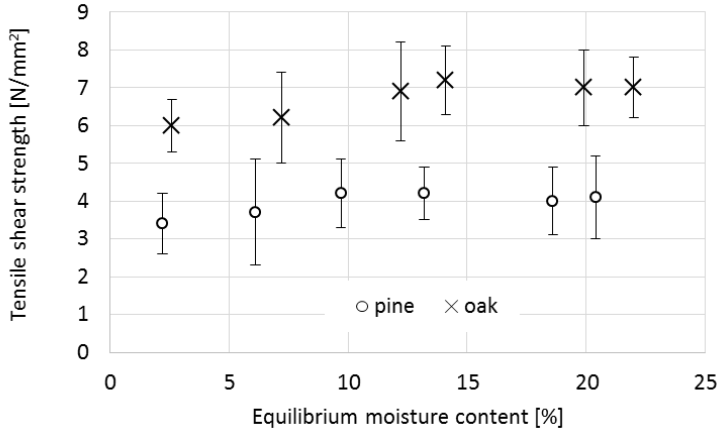

Fig. 3. Tensile shear strength of bonded composites influenced by veneers equilibrium moisture content

When testing the tensile shear strength of the prepared layered composites, the destruction of the samples was also observed. The observation concerned the estimation of the share of the surface of destruction of samples in a wood substance or in bonding line. Based on the observations made, it was found that the destruction of the tested samples occurred generally (over 98% of the total number of samples tested) in the wood substance. It should be added that such a trend is desirable from both producers of composite wood materials, and from the point of view of glue producers. Examples of various forms of destruction of the tested samples are shown in fig. 4.

Fig. 4. An example of bonded sample damaged in wood structure (left) and in bond line (right)

The analysis of the results of the bending strength test as well as the quality of bonding samples of lignocellulosic composites made from various types of wood (pine and oak), conditioned before gluing in different air humidity conditions (from 10% to 95% relative humidity), allows to conclude that there is no significant influence of changed parameters (in this case wood moisture content) on the mentioned strength. Several factors can influence this fact. One of them is the presence of water in the adhesive mass, the amount of which is much higher than in conditioned wood, even with the highest moisture obtained. The second factor is the relatively long pressing time, dictated by the necessity of curing the adhesive mass to achieve a proper joint. During the pressing, heat is transferred through the wood structure, and the temperature of the press shelves used, 120°C, leads to a significant reduction in the humidity of the bonded wood. Hence, the influence of wood moisture content on the mechanical strength of the samples is minimized. For intensive removal of moisture from glued materials, especially when reducing the pressing pressure and opening the press, especially in the case of samples with higher humidity, it was necessary to take special care at this stage to prevent delamination of the glued composite.

CONCLUSIONS

The paper presents the results of research and their analysis in terms of bending strength and bonding quality of lignocellulosic composites made from various types of wood (pine and oak), conditioned before gluing in different air humidity conditions (from 10% to 95% relative humidity).

The research showed that in the studied range of variability of the parameters used, no significant influence of the changed factors (in this case wood moisture content) on the bending strength and the gluing quality was found. Nevertheless, it should be added that the moisture content of wood used to produce the layered composites, can have a significant impact on the parameters of the bonding process, i.e. overheating of the pressed set of wood layers, as well as on the detailed technological guidelines for pressure control in the press as a function of pressing time.

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REFERENCES

Bomba, J., Šedivka, P., Böhm, M., & Devera, M. (2014). Influence of Moisture Content on the Bond Strength and Water Resistance of Bonded Wood Joints. BioResources. https://doi.org/10.15376/biores.9.3.5208-5218

Demirkir, C., Özsahin, Ş., Aydin, I., & Colakoglu, G. (2013). Optimization of some panel manufacturing parameters for the best bonding strength of plywood. International Journal of Adhesion and Adhesives. https://doi.org/10.1016/j.ijadhadh.2013.05.007

EN 310:1994. Wood – based panels. Determination of modulus of elasticity in bending and of bending strength

EN 314-1:2007 Plywood – bonding quality – part 1: Test methods

Frihart, C. R., Yelle, D. J., & Wiedenhoeft, A. C. (2008). What Does Moisture-Related Durability of Wood Bonds Mean? In Proceedings of the Final Conference on COST@34 Bonding of Timber

Kläusler, O., Clauß, S., Lübke, L., Trachsel, J., & Niemz, P. (2013). Influence of moisture on stress-strain behaviour of adhesives used for structural bonding of wood. International Journal of Adhesion and Adhesives. https://doi.org/10.1016/j.ijadhadh.2013.01.015

Mukudai, J., & Yata, S. (1986). Modeling and simulation of viscoelastic behavior (tensile strain) of wood under moisture change. Wood Science and Technology. https://doi.org/10.1007/BF00351586

Zhou, A., Tam, L. H., Yu, Z., & Lau, D. (2015). Effect of moisture on the mechanical properties of CFRP-wood composite: An experimental and atomistic investigation. Composites Part B: Engineering. https://doi.org/10.1016/j.compositesb.2014.10.051