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Influence of alder (Alnus glutinosa Gaerthn.) veneers on selected mechanical properties of layered pine (Pinus sylvestris L.) composites

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Abstract: *Influence of alder (Alnus glutinosa Gaerthn.) veneers on selected mechanical properties of layered pine (Pinus sylvestris L.) composites.* The aim of the study was to analyse the influence of using hardwood veneers in the base layer on selected mechanical properties of composites made of coniferous veneers dedicated for flooring applications. The modulus of elasticity and stiffness at three-point bending were determined in static, dynamic and fatigue tests. All tested mechanical properties of pine-alder composites showed, to a different extent, higher values than composites with a base layer made only of pine veneers.

Keywords: floor, composite, mechanical properties, veneer, hardwood, softwood

INTRODUCTION

Wood is a verified and popular material used in floor production. It is used in public spaces and homes. Due to the different purposes of the spaces, floors have different requirements:

- durability of use,
- easy maintenance,
- aesthetic finish.

Nowadays, floors can be constructed using wood composites. Wood composites can have a layered cross-shaped construction, which results in greater dimensional stability of the structure. In addition, the layered construction makes it possible to use various materials in the top and base layers in the form of thin wooden boards or veneers. There are two-layer structures made of top and base layers (www.jaf-polska.pl/) and three-layer structures in which, apart from the top layer, the base layer is composed of an inner layer and a bottom layer (https://www.barlinek.com.pl). In all these structures, the base layer provides the composites with dimensional stability as well as mechanical properties. The presented work deals with two-layer structures.

The main research trend concerning floors relates to the surface properties of the top (face) layer. In layered composites, it is built of solid or glued wood, as two-strip or three-strip wood flooring. Hence, this kind of research is focused on testing the durability of the top layer and conducted only on separated face layer material (without other layers), for example: hardness (Heräjärvi 2004; Holmberg 2000), strength (Song-Young and Hon-Lin 1999) or top layer examination after material modifications (Grześkiewicz and Krawiecki 2008). Research on the physical and mechanical properties of floor composites for floating floors and sports floors is mainly conducted in view of their elastic properties (Makowski and Noskowiak 2016).

The aim of our study was to analyse the influence of hardwood veneers used in the base layer on selected mechanical properties of composites made of coniferous veneers dedicated for flooring applications.

MATERIALS

Layered composites were produced for the study. Thin oak (*Quercus* L.) boards were used as the top layer – A; while pine (*Pinus sylvestris* L.) and alder (*Alnus glutinosa* Gaerthn.) veneers were used for the base layer – B (Fig. 1). The base layers were made of wood without defects. The oak boards had a thickness of 3 mm ± 0.2. Pine veneers with a thickness of 2.5 mm and 1.5 mm ± 0.1 mm and alder with a thickness of 1.5 mm ± 0.1 mm were arranged in a cross-shape construction. The mean value of modulus of elasticity of pine wood is 12000 MPa and the static bending strength, 100 MPa. The mean value of the modulus of elasticity of alder wood is 9700 MPa, and the static bending strength, 97 MPa [https://www.itd.poznan.pl].

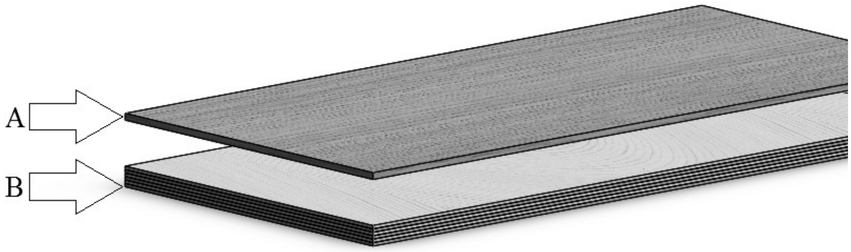

Figure 1. Composite with a two-layer structure: A − top layer, B − cross-shaped base layer

The veneer sheets were cut to 350 mm x 180 mm in such a way that the even layers had fibres arranged perpendicularly to the length of the composite (⊥), hence the odd layers had fibres arranged in parallel to the length of the composite (=). The composites prepared in this way were arranged according to the scheme presented in Table 1. 11 samples from each group were prepared for static and dynamic bending. One composite from each group was used to conduct the fatigue test.

Table 1**.** Layout scheme of individual veneers distinguished by thickness

Sample's mark	Oak thin board [mm]	Pine veneer [mm]	Pine veneer [mm]	Pine veneer [mm]	Pine veneer [mm]	Pine veneer [mm]	Pine veneer [mm]
	=	⊥	=	⊥	=	⊥	=
Pine	3	1.5	2.5	1.5	2.5	1.5	2.5
		Alder veneer [mm]		Alder veneer [mm]		Alder veneer [mm]	
Pine/Alder	3	1.5	2.5	1.5	2.5	1.5	2.5

Urea-formaldehyde glue was used to bond the composite elements. The adhesive application was 180 g/m^2.

Pressing parameters were set as follows:

- time 12 min,
- temperature 120ºC,
- pressure 1.2 MPa.

After gluing, the composites were seasoned. The material was stored at a temperature of 22ºC, and 50% relative humidity, for 28 days. After this time, the geometry of composites was verified.

The geometry verification of the composites was carried out using a mechanical plotter (Fig. 2). The device verifies the geometry in a vertical position. The composites were supported at the base layer and the measurement was carried out on the top layer. The virtual measuring plane was fixed at three base points. The fourth point was adjustable to stabilize the test material during measurement. Measurement accuracy was 0.1 mm/m. Deviations from the theoretical plane of the composites' surface were +/- 1.5 mm.

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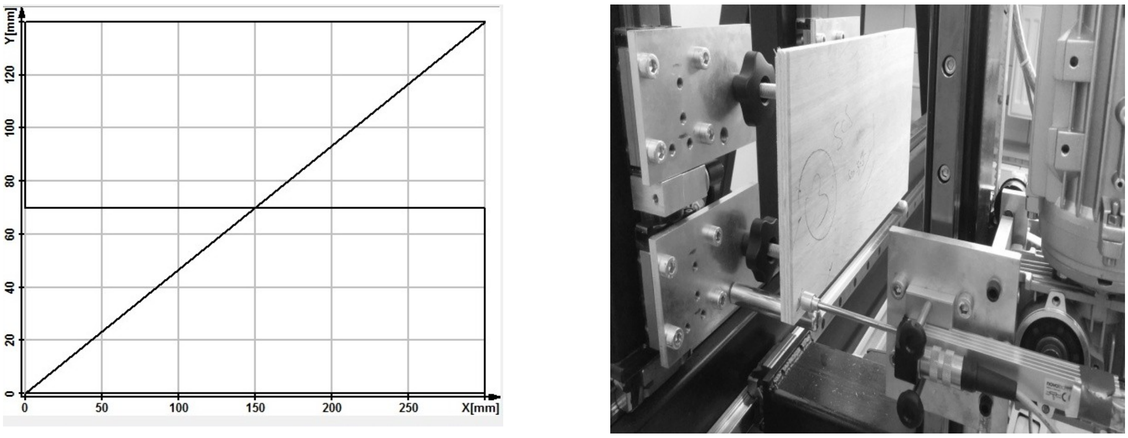

Figure 2. Geometry verification of the composites: a - measuring probe path diagram, b – during measurement

METHODS

The modulus of elasticity for static, dynamic and fatigue tests was specified based on the PN-EN 310:1994 standard, adapted to the samples' dimensions (Boruszewski et al. 2013). The experiment was carried out on a TiraTest 2300 testing machine in the mode of a three-point test. The spacing of supports for the composites was 310 mm (Fig. 3).

a/ b/

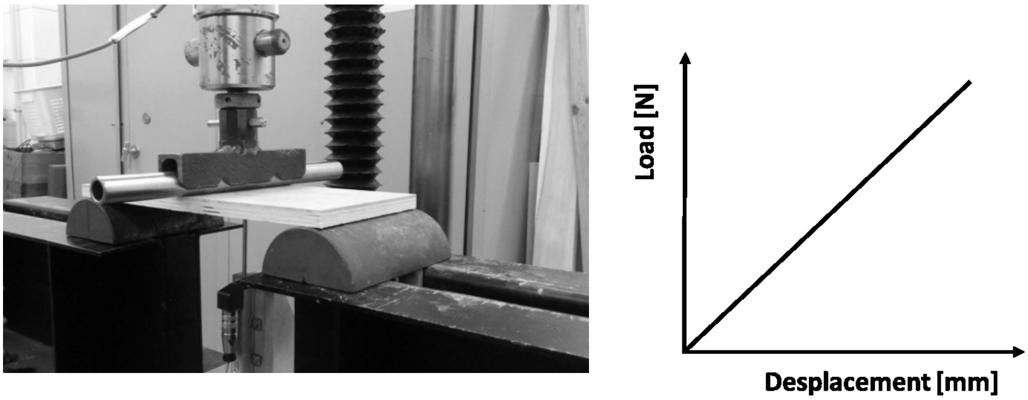

Figure 3. Modulus of elasticity testing: a - testing machine during the test, b – sample of load diagram for desplacement

The measurements were made in the field of elastic deformations of composites, that is within Hooke's law. The formula (1) used to calculate the modulus of elasticity in bending tests was:

$$Em = \frac{L_1^{\,3}(F_2 - F_1)}{4bt^3(a_2 - a_1)} \qquad (1)$$

where:

Em [MPa] – modulus of elasticity,

L_1 [mm] – distance between support centres,

F_2-F_1 [N] – load increase along the straight section of the curve,

F_1 [N] – 10% of load,
F_2 [N] – 40% of load,
b [mm] – sample width,
$a_2 – a_1$ [mm] – increase of the desplacement arrow in the middle of the composite.

Determination of the modulus of elasticity for dynamic bending was the key to determine whether the composite can be used in floating floor conditions and in the field of high dynamic loads such as parquets in sports halls. The tests consisted in dynamically applying a load to the composite. The speed of lowering and raising the traverse was set to 9 mm/s.

In the fatigue tests, the traverse speed was set to 9 mm/s. The tested material was subjected to 50 dynamic load cycles. The study was analysed on the first and then on every tenth cycle.

Stiffness is the ability of a material, connection or structure to counteract deformations caused by external loads. It depends on the shape of the element, its elastic properties, type of load and boundary conditions.

The stiffness of composites under static and dynamic loading conditions was determined from the formula (2) (PN-EN 1995-1-1):

$$k = \frac{Em * b * t^3}{12} \tag{2}$$

where:
k [$MNmm^2$] – stiffness,
E_m [MPa] – modulus of elasticity,
b [mm] – sample width,
t [mm] – sample thickness.

RESULTS

Figure 4 presents the mean results of modulus of elasticity and stiffness in static tests. According to the analysis of modulus of elasticity results, it was slightly higher for the base layer built on a combination of pine and alder woods than for the base layer built only on pine wood veneers. As far as the stiffness is concerned, in case of the base layer built on a combination of pine and alder it was over 20% higher than for the base layer built only on pine wood veneers.

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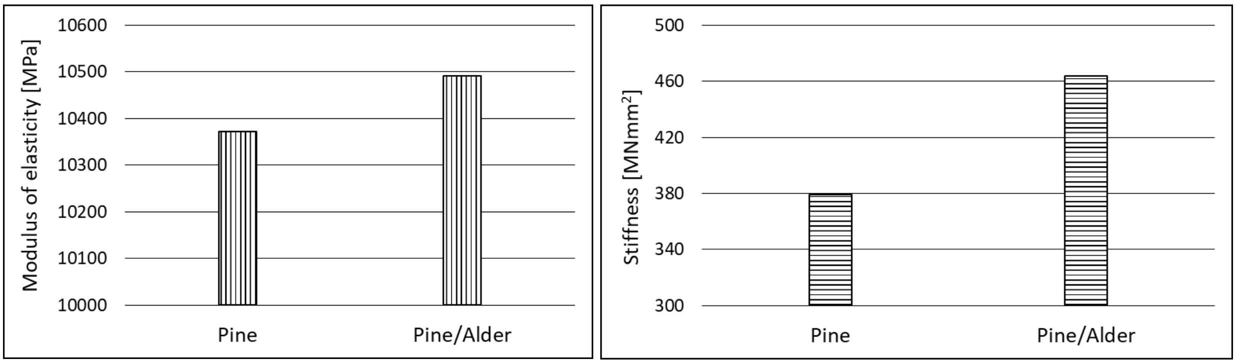

Figure 4. Static bending test: a- modulus of elasticity, b- stiffness

Table 2 presents the mean values of standard deviation and coefficient of variation for the static bending tests. Results for the base layer built on a combination of pine and alder woods are slightly lower in all cases.

Table 2. Statistical data for static bending tests

	Pine		Pine / Alder	
	Em [MPa]	k [MNmm^2]	Em [MPa]	k [MNmm^2]
Standard deviation	940	33	710	28
Coefficient of variation	9%	9%	7%	6%

Figure 5 presents the mean results of modulus of elasticity and stiffness in dynamic tests. According to the analysis of themodulus of elasticity, it was slighlty higher for the base layer built on a combination of pine and alder than for the base layer built only on pine wood veneers. As far as the stiffness is concerned, in case of the base layer built on a combination of pine and alder it was over 20% higher than for the base layer built only on pine wood veneers.

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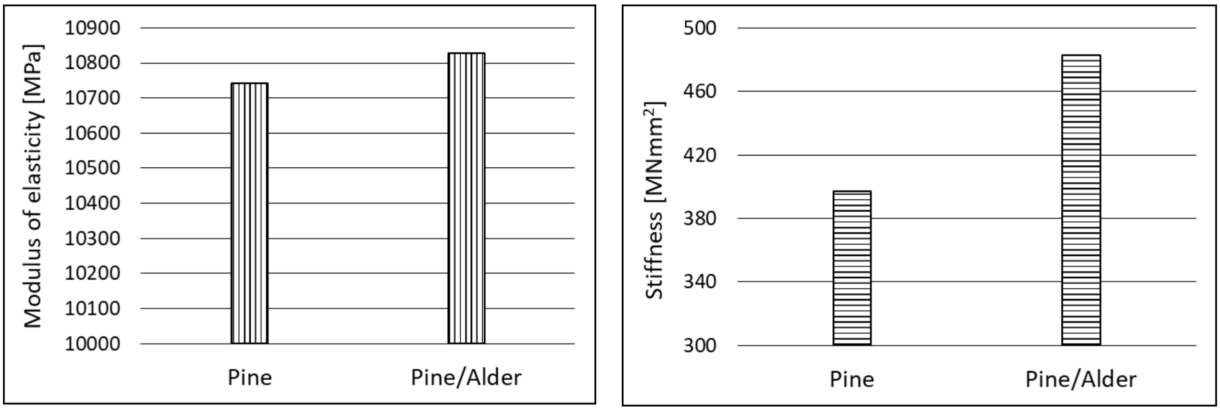

Figure 5. Dynamic bending test: a- modulus of elasticity, b- stiffness

Table 3 presents the mean values of standard deviation and coefficient of variation for the dynamic bending tests. The results for the base layer built on a combination of pine and alder woods are lower. Especially, the standard deviation of modulus of elasticity in dynamic tests is noticeably lower, as well as the coefficient of variation. It means that the application of alder veneers provides stability to the composite structure.

Table 3. Statistical data for dynamic bending tests

	Pine		Pine / Alder	
	Em [MPa]	k [MNmm^2]	Em [MPa]	k [MNmm^2]
Standard deviation	1027	31	644	30
Coefficient of variation	10%	8%	6%	6%

The results of verification of the modulus of elasticity and stiffness in fatigue tests are presented in Figure 6 and Figure 7. Despite the fact that the research was of exploratory nature, they provide important information for future studies.

An analysis of the modulus of elasticity (Fig. 6) shows that it was ca. 17% higher for the base layer built on a combination of pine and alder woods than for the base layer built only on pine wood veneers. It is remarkable that during all the tests, up to 50 cycles, the achieved results show a very stable state for both composites.

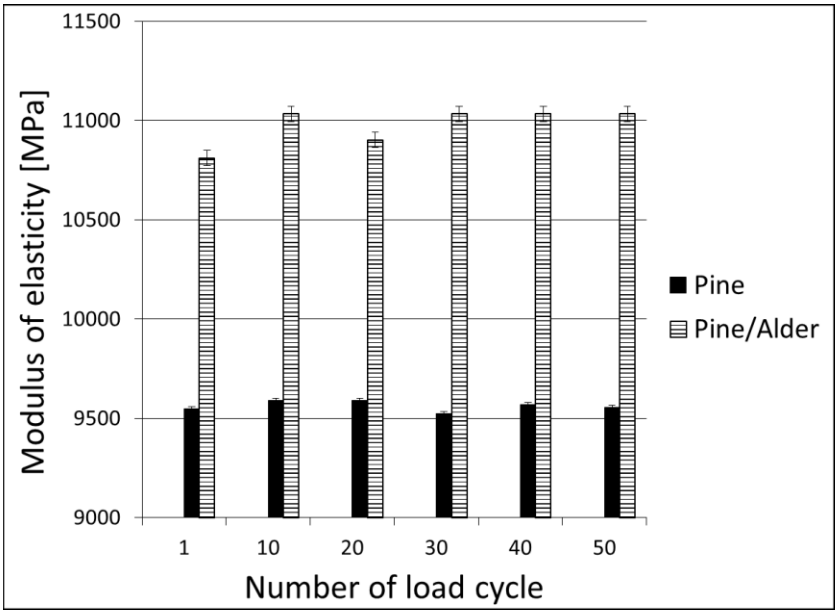

Figure 6. The results of modulus of elasticity in the fatigue test with a breakdown into every 10 cycles including the first cycle

An analysis of the modulus of elasticity (Fig. 7) shows that it was higher for the base layer built on a combination of pine and alder woods than for the base layer built only on pine wood veneers.

As far as the stiffness is concerned, it was over 20% higher for the base layer built on a combination of pine and alder woods than for the base layer built only on pine wood veneers.

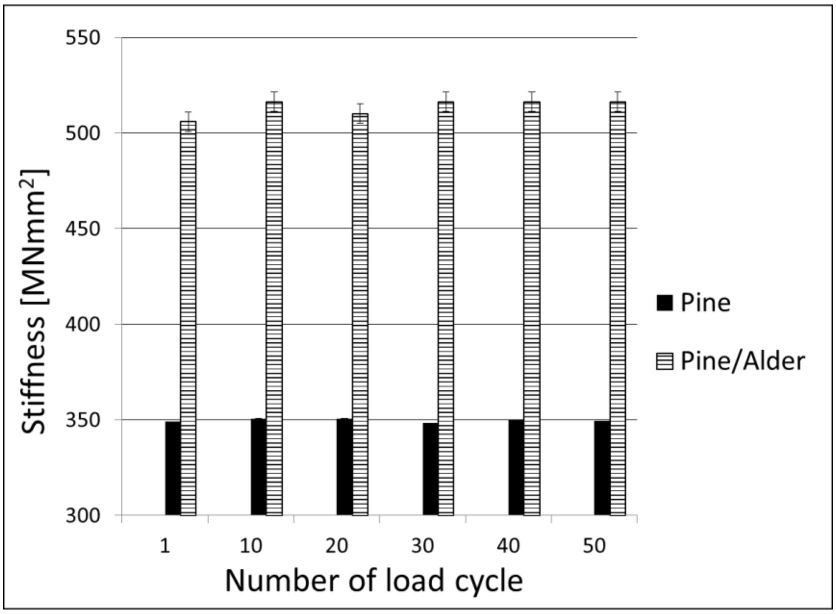

Figure 7. Comparison of stiffness values achieved in the fatigue test

Table 4 presents the mean values of standard deviation and coefficient of variation for the fatigue bending tests. The standard deviation results for the base layer built on a combination of pine and alder woods are higher than for pure pine base layer. This results from much higher values of modulus of elasticity. However, the results of coefficient of variation do not confirm this.

Table 4. Statistical data for fatigue bending tests

	Pine		Pine / Alder	
	Em [MPa]	k [MNmm^2]	Em [MPa]	k [MNmm^2]
Standard deviation	26	0.9	96	4
Coefficient of variation	0.3%	0.3%	1%	1%

CONCLUSIONS

The application of additional alder veneers in the base structure made of pine veneers has a positive effect on the tested mechanical properties of the composites. All the tested values of mechanical properties showed, to a different degree, higher values than in case of composites with a base layer made only of pine veneers, even despite the fact that the modulus of elasticity and bending strength of alder are lower. On this basis we can draw the conclusion that a more homogeneous structure of the diffuse-porous alder wood has a decisive influence on the properties of the composite.

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Streszczenie: *Wpływ zastosowania obłogu olchowego (Alnus glutinosa Gaerthn.) na wybrane właściwości mechaniczne kompozytów warstwowych z drewna sosnowego (Pinus sylvestris L.).* Celem badań była analiza wpływu zastosowania fornirów z drewna liściastego w warstwie podbudowy na wybrane właściwości mechaniczne kompozytów z fornirów iglastych przeznaczonych do aplikacji na podłogach. Określono moduł sprężystości oraz sztywność przy zginaniu trzypunktowym w testach: statycznym, dynamicznym oraz zmęczeniowym. Wszystkie badane właściwości mechaniczne kompozytów sosnowo-olchowych wykazały, w różnym stopniu, wyższe wartości od kompozytów o podstawie wykonanej jedynie z obłogów sosnowych.

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