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Properties of densified laminated aspen wood at bend loading

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Abstract: *Properties of densified laminated aspen wood at bend loading.* Aspen is a fast growing tree, one of the less economically important plants. For usage of this wood it is necessary to know its original characteristics and properties in the form of laminar - laminated timber. In our work we were focused on examining the mechanical properties of densified and laminated timber made from aspen. We have investigated bending strength and modulus of elasticity of densified and laminated aspen wood glued with polyurethane adhesive.

Densified wood and laminated wood has better mechanical properties than non – densified wood.

Keywords: aspen, pressing, density, densified, densification, degrees of compaction, laminated wood, bending strength, modulus of elasticity

INTRODUCTION

Aspen wood *(Populus tremuloides)* belongs to wood species less economic used. Aspen wood is characterized by longer fibres, lower density, and interesting light almost white colour. One of the possibilities how to enlarge aspen wood utilization is to modify its mechanical properties by increasing its density. By increasing the density it is possible to improve strength properties of wood; that gives conditions for its usage in production of bentwood furniture. Improvement of mechanical properties by compressing is described in work by Chuchrjanskij (Chuchrjanskij 1953).

In our research we aimed at change of mechanical properties of aspen wood by:

a) modifying wood density by pressing - densified wood
b) layering i.e. production of laminated wood

We evaluated the influence of mentioned factors on bending strength and modulus of elasticity. Wood was pressed to three degrees of compaction. At laminated wood we combined layers of pressed and non-pressed wood.

MATERIAL AND METHODS

To research chosen mechanical characteristics (bending strength and modulus of elasticity) of aspen wood, we prepared three basic sets of specimens. The first set consisted of native massive wood specimens. The second test set consisted of specimens from pressed massive wood (densified wood) and the third one of laminated wood.

Pressing treatment was processed in radial direction in three degrees of compaction – 30, 40, and 50 % from initial thickness, with no consequent stabilisation in the press (fig. 1). Wood moisture content at pressing was 16 %, and before bending test the moisture content was conditioned to the value of 12 %.

By the reason to evaluate wood density changes when pressed, the values of density before pressing and after pressing were measured.

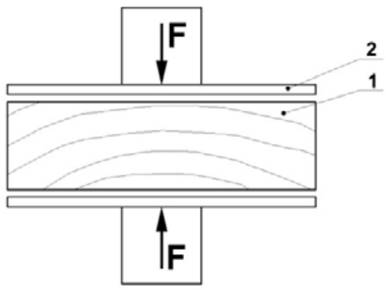

Fig. 1 Pressing of wood in radial direction; 1 – pressed wood, 2 – press sheets

Laminated wood was made from three layers in various combinations of pressed and non-pressed wood. We prepared five sets of laminated wood – combinations of layers:

- all layers from non-pressed wood (type N),
- all layers from pressed wood (type Z),
- laminated wood with one layer from pressed wood in top, middle, or down layer (type VL, type SL, type SPL),
- laminated wood with two layers of pressed wood in outer layers (type KL).

Way of lying is figured in fig. 2. Thickness of individual layers – lamellas was 8.33 mm and they were glued together with the adhesive Jowat Power PUR 687.40 at ambient temperature in one-storey press.

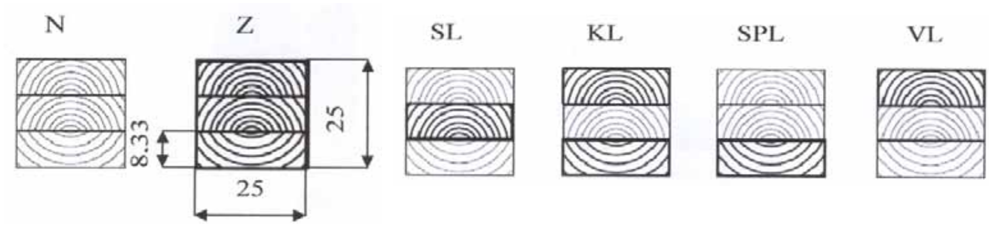

Fig. 2 Combinations of three-layer laminated aspen wood [Raučina 2011]

 lamella from native wood (N)  lamella from pressed wood (Z)

Specimen dimensions for bending test were 25 x 25 x 550 mm. Bending test was done according to test scheme represented in fig. 3; measured values were evaluated according to the relations 1 and 2 for calculation of limit of strength and limit of modulus of elasticity:

- **bending strength:**

$$\sigma_{oh} = \frac{3 \,.\, F_{max} \,.\, l_o}{2 \,.\, b \,.\, h^2} \quad \text{[MPa]} \qquad (1)$$

where: F_{max} – force at failure of specimen [N],
l_0 – distance between supports [mm],
b – width of specimen [mm],
h – thickness of specimen [mm].

- **modulus of elasticity**:

$$E = \frac{(F_{40} - F_{10}) \,.\, l^3_o}{4.\, b.\, h^3 \,.\, (y_{40} - y_{10})} \quad [MPa] \qquad (2)$$

where: F_{40} – 40 % from maximal force [N],
F_{10} – 10 % from maximal force [N],
y_{40} – deflection corresponding to force F_{40} [mm],
y_{10} – deflection corresponding to force F_{10} [mm].

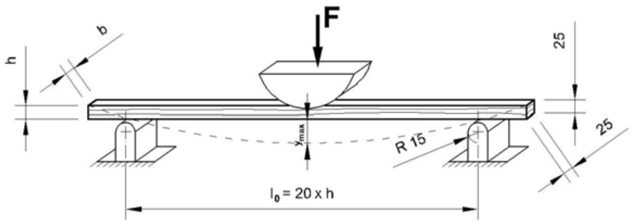

Fig. 3 Bending test

RESULTS AND DISCUSION

Mechanical treatment of aspen wood by pressing in radial direction at three levels of compaction and wood moisture content of 16 % resulted in **increased density of wood.** Increasing the degree of compaction of massive aspen wood the density increases. When compared with density of non-pressed aspen wood (ρ_{12} = 490 kg.m^{-3}), at first degree of compaction (30 %) density increased by 12.4 %, after the second degree of compaction (40 %) the increase was by 23.5 %, and after third degree of compaction (50 %), the increase was as by 33.3 % and wood density reached the value of ρ_{12} = 653 kg.m^{-3} (Tab. 1).
The change of density must necessarily be evaluated with regard to how initial value of density was; that is very variable at aspen wood. It varied in the range ρ_0 = 463 ÷ 526 kg.m^{-3}. Authors give various values of density. Požgaj et al. (1997) gives the value ρ_0 = 350 ÷ 400 kg.m^{-3}. Other authors state ρ_0 = 400 kg.m^{-3} (Regináč, 1990), ρ_0 = 430 kg.m^{-3} (Dubovský, 1997), ρ_0 = 482 kg.m^{-3} (Fellner a kol., 2007), ρ_{12} = 390 kg.m^{-3} (Wood handbook 1990).

By pressing not only density was changed, but there were changed also mechanical properties of aspen wood. **Bending strength** of massive wood across the fibre in radial direction was increased with increasing degree of compaction. At non-pressed wood we reached the value of strength σ_{12} = 84.5 MPa. The increase of strength was stronger up to 40 % of compression, where the increase was by 23.3 % and corresponding strength was σ_{12}= 104.1 MPa. When degree of compaction was increased into 50 %, the increase was by 24 % and strength reached the value only σ_{12}= 104.7 MPa. Considering the fact that strength increased only by 0.7 %, when compared with compression of 40 %, we can assume that in this case, some failure in the wood structure happen and that is why the strength is increased only by a little.

M**odulus of elasticity** was not influenced much by compression of wood. The highest increase was reached at 40 % compression, by 3.5 % compared to non-pressed wood. At 50 % compression we observed the decrease by 8 %; based on that fact we can assume that stiffness was decreased.

Three-layer **laminated aspen wood** reaches higher values of bending strength in comparison with native massive wood by 9 ÷ 23%. From the point of view of combinations of layers, the best results were reached at laminated wood, with one layer of pressed wood (into 50 %) in position on the top – type VL. The strength was increased by 23 % to the value of σ_{12}= 103.7 MPa and modulus of elasticity by 4 % to E_{12} = 9 693 MPa. By the combination of two pressed layers (to 40 %) – type KL, the strength was increased by 21 % and by combination of three layers (50 %) – type Z, it was increased only by 18 %. Modulus of elasticity in these cases was lower than at native massive wood.

Tab. 1 Monitored properties of massive and laminated aspen wood m. c. =12% (Raučina 2011)

Matter		Degree of compaction [%]	Density ρ_{12} [kg.m^{-3}]	Bending strength σ_{12} [MPa]	Modulus of elasticity E_{12} [MPa]
Massive wood	Non-pressed	-	489,7	84,45	9323,5
	Pressed	30	550,46	103,23	9006,6
		40	604,61	104,12	9647,5
		50	652,72	104,7	8558,5
Laminated wood - **N**	Non- pressed	-	498,5	91,91	8589,6
Laminated wood - **Z**	Pressed	30	586,99	97,89	7552
		40	595,64	81,97	9267
		50	678,17	99,7	7315,2
Laminated wood - **SPL**	N N Z	30	521,02	91,08	8100,1
		40	549,48	93,18	7179
		50	563,85	86,95	8276,1
Laminated wood - **VL**	Z N N	30	533,12	97,98	8232,2
		40	530,96	92,75	9190,6
		50	556,13	103,65	9692,9
Laminated wood - **SL**	N Z N	30	514,79	87,38	8353,8
		40	529,57	92,63	7906,1
		50	554,03	94,99	7563,6
Laminated wood - **KL**	Z N Z	30	555,08	99,88	7379,2
		40	570,95	102,12	9043,8
		50	610,9	98	6490,6

CONCLUSION

Modifying aspen wood by pressing we can change wood properties. By pressing it, the density is increased and mechanical properties are also changed. Without any problems we can press aspen wood to 40 % from the initial thickness. We obtain higher density and bending strength by 23 %, as well. Increasing a degree of pressing to 50 % is possible, but improvement of mechanical properties is not so evident – only by 1 % in comparing with compression to 40 % (σ_{12}= 104.7 MPa and E_{12} = 8 559 MPa).

Another way how to improve mechanical properties is layering. At three-layer laminated aspen wood we reached increasing of mechanical properties by 9 ÷ 23% when compared with massive wood. From the view point of improvement of properties the best type KL with two outer pressed layers (40 %), where average increase of bending strength was by 18.5 % in comparison with non-pressed massive wood. Layering with one pressed layer on conclave side – type VL caused mean improvement by 16 % and all three pressed layers – type Z only 15 % increase when compared to non-pressed massive wood. From the results we can conclude that combination of layers of pressed and non-pressed wood enables, in a certain range, to vary the properties of laminated aspen wood. This type of wood can be used in a branch of stronger or more elastic materials when compared with native massive wood.

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Streszczenie: *Własności mechaniczne zagęszczonego warstwowego drewna osiki przy zginaniu*. Osika jest szybko rosnącym gatunkiem drewna, o mniejszym znaczeniu ekonomicznym. Aby lepiej wykorzystać ten materiał, należy poznać jego oryginalne własności, oraz własności postaci zmodyfikowanej, warstwowej. Skupiono się na własnościach mechanicznych zagęszczonego I warstwowego drewna osiki. Badano moduł sprężystości oraz wytrzymałość przy zginaniu drewna naturalnego oraz zagęszczonego warstwowego klejonego klejem poliuretanowym. Drewno warstwowe ma lepsze własności mechaniczne niż naturalne.

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