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The properties of sandwich panels made of standard wood-based panels

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Abstract. *The properties of sandwich panels made of standard wood-based panels.* The properties of sandwich panels made of standard wood-based panels were examined. Particleboards, MDF and OSB panels as well as plywood were used as internal and external layers of panels. Two types of adhesives: PUR and PVA were used to bind the layers. The physical and mechanical properties of glued sandwich panels were investigated. It was found out that OSB panels covered with plywood have the highest MOE and MOR values, and the panels with an internal layer composed of MDF have the lowest of WA and TS. It has been shown that regardless of the materials used, a panel glued with PUR achieves higher mechanical properties and the lowest WA and TS values.

Keywords: wood-based panels, sandwich wood panels, mechanical properties, physical properties

INTRODUCTION

One of the most effective methods of controlling the mechanical properties of plate elements is to use sandwich structures. Layer structures are increasingly becoming structural and non-structural elements used in construction. Sandwich constructions are usually made of two thinner face layers with high stiffness and strength and a flexible and light core that maintains distance between the surfaces and resists deformation. An inner core is very often characterized by insulating properties. By changing the material, thickness and type of core and outer layers, sandwich structures with various properties and performance can be obtained (Lakreb et al. 2015, Smardzewski2019). In wooden constructions, fibreboards (Kawasaki et al. 1999, Kawasaki et al. 2006, Kawasaki et al. 2003, Lakreb, et al. 2018), cork (Kawasaki and Kawai 2006, Lakreb et al. 2015) or plastics, e.g. PVC (Kljak and Brezović 2007) are typically used for a middle layer as insulating boards with structural properties. The entire filling of the middle layer is very often replaced with structural filling (Banerjeea and Bhattacharyyab 2011, Smardzewski 2019, Auriga et al. 2020). Outer layers are most often made of veneer or plywood, but occasionally also of other materials like for instance particleboard (Klímek, et al. 2016). At times the middle layer made of wood materials, e.g. of plywood, was covered with non-wood coatings such as aluminium and glass, a composite reinforced with carbon fibre, and a polymer cover or a flax-reinforced polymer (Susainathan et al. 2018). It should be noted that the layered systems also include typical wood-based panels covered with laminates or protective and decorative papers (Nemli and Çolakoğlu 2005). Adhesive resins commonly used in woodwork are usually employed to bind individual layers into a sandwich panel. In order to obtain new quality material, e.g. for construction, it is possible to employ a simple method consisting in binding into a sandwich structure of typical wood materials, that are well known and employed in the wood industry, such as particleboard, OSB, MDF plywood and the like. The results of the presented research suggest that these sandwich panels can be used as construction materials for producing furniture, panels or partition walls in building construction in indoor applications, bringing environmental benefits and cost-effectiveness as well. Therefore, it was decided to examine the usefulness of typical wood-based materials for manufacturing sandwich panels as construction materials.

MATERIALS AND METHODS

In the study three types of commercial wood-based panels: raw particleboard (PB), MDF and OSB were used for an inner layer. Birch plywood (PLY) was used for outer layers. The characteristics of the panels is shown in Table 1.

Table 1. Characteristics of panels used in the research.

Panels	Thickness	Density
	mm	kg/m^3
PB	12.2 (1.2)	705 (2.6)
OSB	11.9 (0.8)	630 (2.9)
MDF	12.3 (0.5)	771 (1.9)
PLY	3.64 (0.7)	639 (2.0)

Standard deviations in parentheses

Two kinds of glue were used as adhesive material: polyvinyl acetate (PVA) - Rakoll Express 25D, and polyurethane (PUR) - Chemolan B45. Standard sized commercial panels were trimmed to the 500 x 500 mm^2 format and then stored in the laboratory for 7 days (air temperature 23°C, humidity 50%). After that they were characterized by on average 8% moisture content. Afterwards a half of recommended quantity of glue was applied on one of the sides of outer panels. Inner panels were coated with glue on both sides, but a half of recommended quantity was applied on each side. The plates prepared in this way were then set together in packages. Outer panels in the packages were each time arranged in such a way that wood fibres in PLY were oriented parallel to both outer layers. In order to obtain panels composed only of PLY, five layers of plywood were glued together, maintaining the cross arrangement of plywood veneers. The panels were glued in a cold press using a pressure of 0,45 MPa for 24 hours at a constant temperature of 23°C. The samples of sandwich panels manufactured in the above-described way are shown in Figure 1.

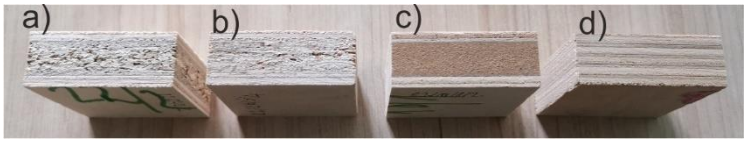

Figure 1. Tested sandwich panels with an inner layer made of: a) PB, b) OSB, c) MDF and d) glued PLY

The sandwich panels were cut to obtain samples whose dimensions were 50 x 410 mm^2. The mechanical properties, modulus of elasticity (MOE) and modulus of rupture (MOR) of the tested panels were evaluated in relation to flexural properties. Flexural tests were performed according to PN-EN 310, using the Instron 3367 machine. Additionally, the influence of soaking the panels in water for 24 hours on their physical properties, water absorption (WA) and thickness swelling (TS) was investigated. Ten replicates were run for each test. All tests were performed at a room temperature (23°C) and at a constant relative humidity (50%).

RESULTS

The obtained data were statistically analysed employing the Statistica 13. In order to determine the impact of the examined factors, the one-way analysis of variance (ANOVA) was used. The significance of differences between the mean values of a given property was evaluated by Tukey's HSD test and presented in Figures 2 and 3. The same letters indicate that there is no significant difference (at $\alpha = 0.05$) for a given property between different kinds of panels compared. The MOE and MOR values of materials used to produce sandwich panels are presented in Table 2.

Table 2. Mechanical properties of panels used

Kind of panels	MOE	MOR
	MPa	
PB	2452 (98.1)	10.8 (0.4)
OSB	5516 (275.8)	22.8 (1.1)
MDF	4050 (121.5)	39.4 (1.2)
PLY	10363 (310.9)	92.9 (2.8)

Standard deviation in parentheses

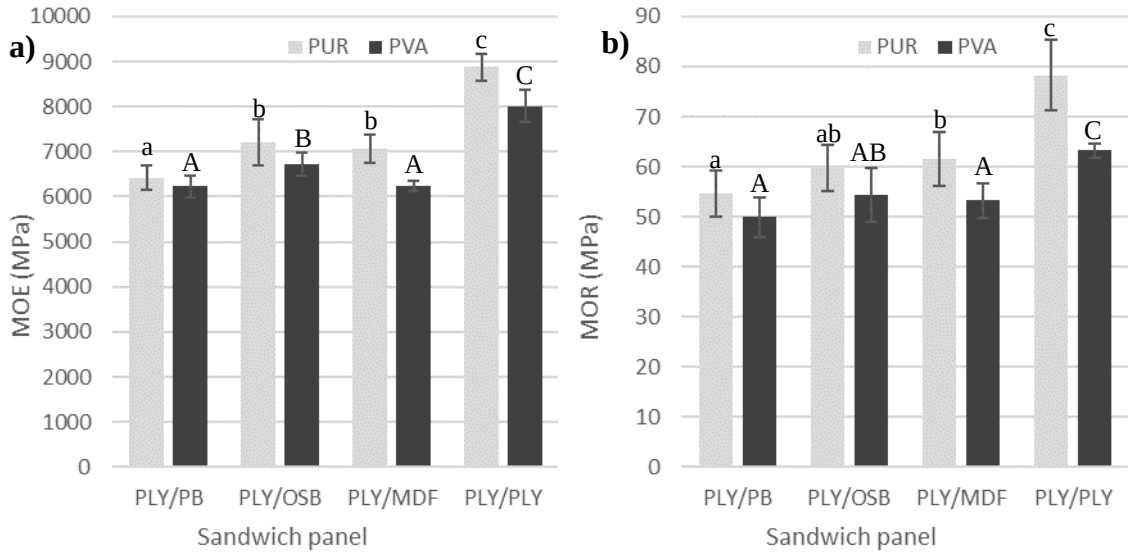

Figure 2. Effect of material used as an inner layer and type of glue on: a) MOE, b) MOR of sandwich panels

The figure 2 shows the comparison of the MOE and MOR values of tested sandwich panels. Having analyzed the MOE (Fig. 2a), one can conclude that it significantly depends on the material used for an inner layer, and as was expected its highest value was recorded for sandwich panels composed of PLY glued with PUR and PVA, 8875 and 8012 MPa, respectively. The use of PB for a middle layer results in the lower MOE value by 28 and 22% for PUR and PVA, respectively, while for sandwich panels containing OSB and MDF panels, the lowering of the MOE value is lesser and amounts on average to 19%. It is also worthwhile considering the impact of glue applied. The using of PUR for gluing sandwich panels gives higher MOE values by 3, 6 and 13% for sandwich panels containing PB, OSB and MDF, respectively. In the case of gluing only PLY, this increase amounted to 11%. Significantly greater differences between the materials can be observed in the case of the analysis of MOR (Fig. 2b). As regards sandwich panels made of only PLY, one can state that the use of PB, OSB, and MDF as an internal layer in sandwich panels gives lower MOR values, by 30, 24 and 21%, respectively, when PUR was used, and by 21, 14 and 16%, respectively, when PVA was used. Also the kind of glue applied is very important for this mechanical property. The use of PUR instead of PVA increases the MOR value from 9% for sandwich panel made of PB to 24% for the set made of PLY.

In addition to the results of the analysis presented above, it is also worthwhile paying special attention to advantages obtained by gluing a panel characterized by lower mechanical properties with the material characterized by higher ones. Table 3 shows the percentage of the increase in the MOE and MOR values of sandwich panels glued with PUR and PVA in relation to the MOE and MOR values of the materials constituting the inner layer of the sandwich panels. When analysing these results, one can see that the greatest advantages are obtained

when PB is bonded to PLY. In this case the increase in the MOE value of sandwich panel is on average 158%, and the increase in the MOR value is on average 386% (regardless of adhesive used) in comparison to the MOE and MOR values of PB. One should note that the higher advantages in relation to MOE and MOR are each time revealed by these sandwich panels which were glued with PUR.

Table 3. The relative values of MOE and MOR of sandwich panels in relation to these properties of the materials used for the inner layers.

Kind of panels	Mechanical property			
	MOE		MOR	
	PUR	PVA	PUR	PVA
	(%)			
PLY/PB	161.9	154.5	407.3	364.2
PLY/OSB	30.7	21.7	140.7	119.2
PLY/MDF	74.5	54.1	56.1	35.3
PLY/PLY	-14.4	-22.7	-15.8	-31.9

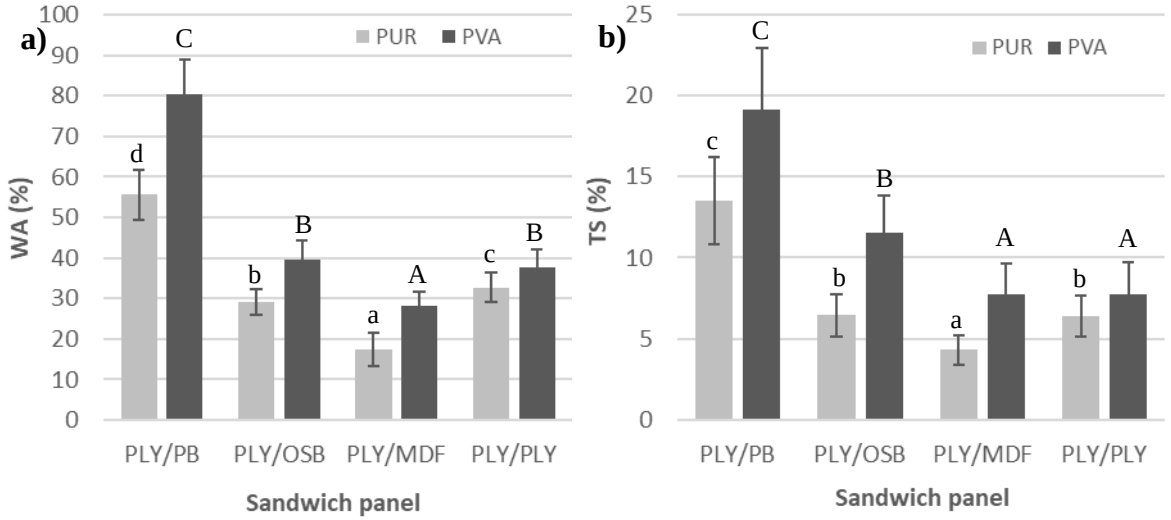

Figure 3. Physical properties of panels after 24 hours of soaking in cold water: a) WA, b) TS

The WA (Fig. 3a) and the TS (Fig. 3b) of the produced sandwich panels after soaking them in water for 24 hours were also analyzed. As the hygroscopic properties of the materials used are known, therefore, it was not surprising that the lowest value of WA was recorded for the sandwich panel containing MDF, that is 17% for the set with PUR and 28% for the one with PVA. When an internal layer is made of PB, the WA value of such a sandwich panel increases on average twice, but when it is made of OSB, the increase is much lower and amounts to 70% for PUR and 40% for PVA. It is also worthwhile noting that the set made of only PLY has the higher a WA value than the one made of MDF panel, by 90% when PUR was used, and by 34% when PVA was used. It was also the case with the TS results. The lowest TS results were recorded for the panel containing MDF, 4.3 and 7.7% for PUR and PVA, respectively. The use of PB significantly increases the TS of sandwich panel, although the latter is significantly dependent on the kind of used glue, by 241% for PUR, and 148% for PVA. In the case of sandwich panel containing OSB panel, the increase in the TS value, in comparison to the set with MDF panel, regardless of adhesive used, amounts to 49%.

CONCLUSIONS

1. By using the typical wood-based panels as components of a sandwich panel, it is possible to create layer systems with the expected mechanical and physical properties.
2. Regarding MOE and MOR, the greatest benefits are obtained by covering with PB plywood, while much smaller in the case of covering with MDF and OSB.
3. The sandwich systems consisting of outer layers made of PLY and core layers made of standard wood-based panels are in general characterized by comparable MOE and MOR values, however, they are lower on average by about 20% than those of PLY/PLY systems.
4. Using PUR adhesive to produce sandwich panels slightly improves their mechanical properties, but significantly reduces WA and TS as compared to sandwich panels glued with PVA.
5. The highest WA and TS values are possessed by those analyzed sandwich panels which have an internal layer made of PB, while the lowest ones by those which have an internal layer made of MDF.

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Streszczenie: *Właściwości płyt warstwowych wykonanych ze standardowych płyt drewnopochodnych*. Zbadano właściwości płyt warstwowych, wykonanych ze standardowyc płyt drewnopochodnych. Jako warstwę wewnętrzną i zewnętrzną płyt zastosowano odpowiednio płyty wiórowe, MDF i OSB oraz sklejkę. Do połączenia warstw zastosowano dwa rodzaje klejów: PUR i Rakoll. Zbadano właściwości fizyczne i mechaniczne klejonych płyt warstwowych. Stwierdzono, że płyta OSB oklejona sklejką ma najwyższe MOE i MOR, oraz że najniższą WA i TS posiada płyta ze środnikiem z MDF. Wykazano, że niezależnie od zastosowanych materiałów, płyta warstwowa klejona klejem PUR osiąga wyższe właściwości mechaniczne oraz najniższe WA i TS.

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