Drewno. Pr. Nauk. Donies. Komunik. 2011, vol. 54, nr 185

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THE COMPARISON OF PROPERTIES OF THREE-LAYER CELLULAR MATERIAL AND WOOD-BASED PANELS

In recent years a reduced weight cell panel, whose trade mark is Dendrolight, has gained worldwide recognition thanks to the opening of an experimental factory in Austria and the start-up of a new industrial factory in Latvia with manufacturing capacity of 65 thousand m³ cell board material per year. Hitherto the internal layer of cell panel of cellular wood material type has been produced mainly from softwoods like Norway spruce (Picea abies L.) or Scots pine (Pinus sylvestris L.) covered with plywood, solid wood, particleboard or other material. The reduced weight cell panel has many applications in the furniture industry, internal cladding, door production, the transport manufacturing industry, and possibly in the construction panel production. The essential goal of the research was to identify possible applications of aspen (Populus tremula L.) wood, which is a common broad-leaved tree in Latvia, as an alternative material to Norway spruce in the production of reduced weight cell panel. The aim of the initial research was to investigate some physical and mechanical properties of aspen cell panel covered with aspen and plywood as well as to compare these physical and mechanical properties with the properties of wood-based panels.

The following raw materials were used: finger jointed aspen for internal layer; finger jointed aspen and three-layer birch plywood for external layer; polyurethane and polyvinylacetate adhesives for internal and external layer gluing. Tests of obtained aspen panel were carried out in accordance with current test standards for testing of panel and timber properties. The following panel parameters were determined: moisture content, density, swelling in thickness after 24-hour immersion in water, tensile strength, three-point bending strength and modulus of elasticity, and four-point bending strength. A relevant conclusion: panels of cellular wood material type produced from aspen wood have similar physical and mechanical properties to such cell panels produced from spruce wood.

Keywords: cellular wood material, aspen, cell panel

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Introduction

Hitherto reduced weight cell panels have many non-structural applications. To add another species to the group of applicable wood species, research on aspen wood cell panel was carried out. The cell panel internal layer was made of grooved solid aspen wood and two external layers of 3 mm thin solid aspen wood or of three-layer birch plywood. The structure of the cell panel is shown in fig. 1. As regards the use, the essential requirements for non-structural cell panel are its density, thickness swelling, strength, and stiffness properties. The essential goal of the research was to identify possible applications of aspen (*Populus tremula* L.) wood, which is a common broad-leaved tree in Latvia, as an alternative material to Norway spruce (*Picea abies* L.) in the production of reduced weight cell panel.

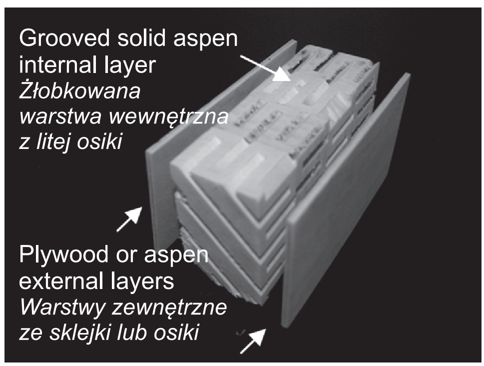

Fig. 1. Structure of aspen cell panel
Rys. 1. Struktura osikowej płyty komórkowej

The aspen cell panels for experimental tests were manufactured in the production unit and laboratory of the Forest and Wood Product Research and Development Institute ltd.

Materials and methods

Raw material

To produce reduced weight aspen wood cell panels, industrially produced aspen timber with the nominal dimensions of 30×90×1500 mm and volume of 1.5 m^3 was obtained. Technical data of the finger jointed aspen wood was as follows: finger length – 10 mm, finger pitch – 3.8 mm, tip gap – 0.6 mm. The average moisture content of the boards was 10 %. Polyvinylacetate adhesive Rakoll PVA_C 3 was used for aspen finger jointing. The finger joints were visible on the flat side of the board. The cell board slices were covered with material of two types: 3-layer birch plywood of the thickness of 3 mm or a layer of aspen solid wood of the thickness of 3 mm. Fig. 2 shows a schematic illustration of the manufacturing process of reduced weight aspen panels in the laboratory.

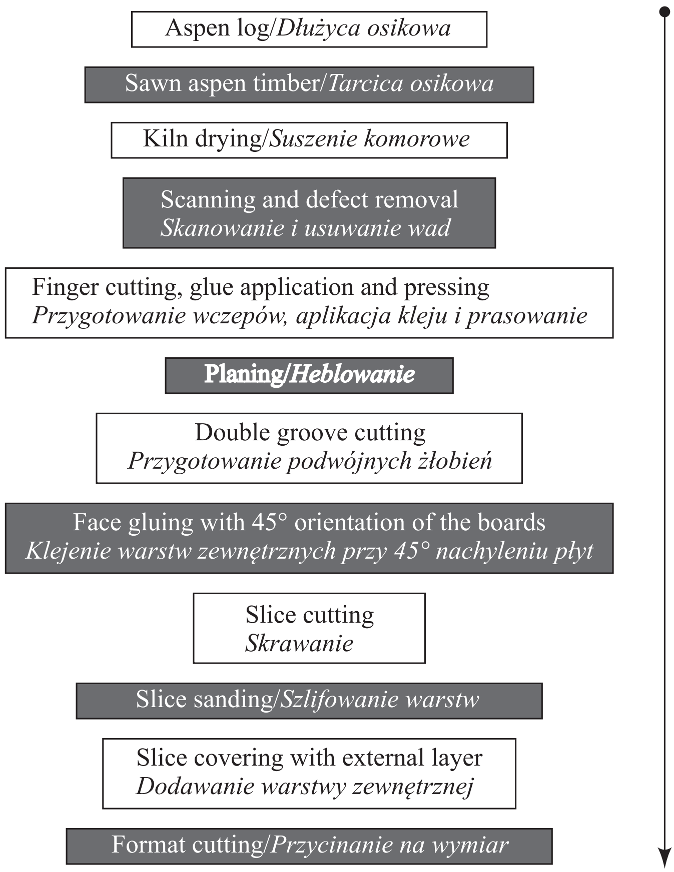

Fig. 2. Schematic illustration of the manufacturing process of reduced weight aspen panels
Rys. 2. Schematyczne przedstawienie procesu wywarzania osikowych płyt o obniżonej gęstości

Processing

Before further processing, all aspen boards were conditioned in the standard atmosphere (20±2°C; 65±5%) to reach a constant mass and an average moisture content of 12%. The cross-section dimensions of 25×91.6 mm were obtained by planing. After planing, double faced grooves were cut into the flat faces of boards with the following dimensions of the grooves: depth 21 mm, pitch 6.2 mm, width 3 mm (fig. 3.).

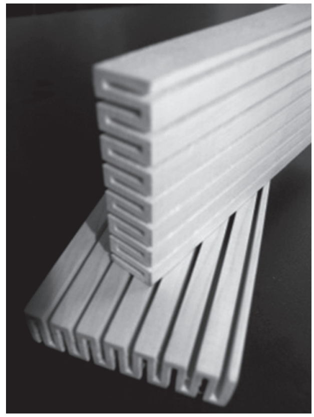

Fig. 3. Aspen board with grooves
Rys. 3. Płyta osikowa ze *żłobkowaniem*

Gluing

Two types of non-structural one-component adhesives, i.e. polyurethane Dana Pu 2116 (PU) and polyvinyl acetate Danafix 447 (PVA), were used in both face gluing of grooved boards and slice covering with external layers. The average amount of adhesive applied in face gluing of the boards was 176 gm^{-2} for PVA glue and 137 gm^{-2} for PU adhesive. The average amount of adhesive applied in slice covering with plywood and aspen was 226 gm^{-2} for PVA adhesive and 228 gm^{-2} for PU adhesive. Face gluing and slice covering was carried out under the pressure of 0.2 MPa and at the pressing time of 60 minutes for PVA adhesive and 90 minutes for PU adhesive. After face gluing and conditioning, 34 mm thin cell board slices were cut for internal layer manufacturing. Before covering all cell slices were sanded to avoid local indentations. Fig. 4 shows the aspen cell slices before covering them with plywood or aspen.

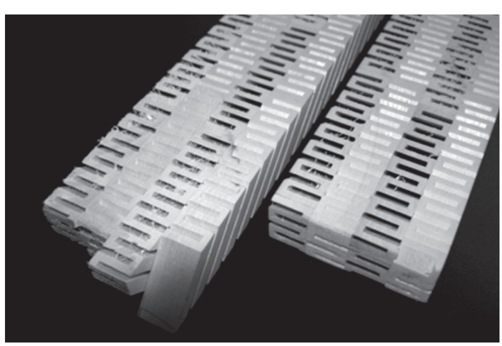

Fig. 4. Aspen cell slices for panel internal layer
Rys. 4. Warstwy komórkowe z osiki przeznaczone na warstwę wewnętrzną płyty

Panel type

Preparation of the specimens was carried out with the aim of determining their physical and mechanical properties. Four types of aspen cell panels were produced: type 1 – face gluing and slice covering with PU adhesive, 3 mm thin aspen wood in external layer; type 2 – face gluing and slice covering with PU adhesive, 3 mm birch plywood in external layer; type 3 – face gluing and slice covering with PVA adhesive, 3 mm aspen wood in external layer; and type 4 – face gluing and slice covering with PVA adhesive, 3 mm birch plywood in external layer. At least 10 specimens were tested for each type of panel and each property. In total 280 specimens were tested. Fig. 5 shows reduced weight aspen panels covered with plywood and aspen wood.

Test methods

After conditioning and before testing, average moisture content was determined according to LVS EN 322 standard for 20 specimens of each type of aspen panel. The thickness of the specimen for moisture content test was the same as of the panel, i.e. 40 mm. Other dimensions were according to the standard. An average density of the 20 specimens of each panel was determined according to LVS EN 323 standard. For all four types of panels an average swelling in thickness after 24 hour immersion in water was determined for at least 10 specimens according to LVS EN 317 standard. At least 10 specimens from each panel were used to estimate the gluing quality between the external layer and the cell material according to LVS EN 319 standard. 3-point bending strength and modulus of elasticity were evaluated for at least 15 specimens for each type of panel according to LVS EN 310 standard.

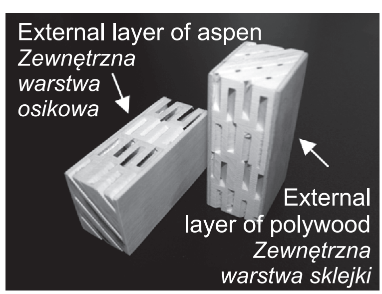

Fig. 5. Reduced weight aspen panels covered with aspen and plywood
Rys. 5. Płyty osikowe o obniżonej gęstości pokryte osiką i sklejką

The length of the specimen parallel to the grain of the external layer was 900 mm, thickness 40 mm and width 50 mm. 4-point bending strength according to point 13 of LVS EN 408 standard was evaluated to compare it with the results of 3-point bending strength. In order to compare the mean values of physical and mechanical properties, basic statistical data processing methods were applied to determine average, standard deviation (s) and variation coefficient (v).

Results

The results of determination of aspen cell panel physical and mechanical properties are presented in table 1.

Table 1. Physical and mechanical properties of reduced weight aspen panels
Tabela 1. Właściwości fizyczne i mechaniczne płyt osikowych o obniżonej gęstości

Property *Właściwość*	Type of panel *Rodzaj płyty*			
	External layer of aspen + PU adhesive Type -1 *Zewnętrzna warstwa osika+ klej PU Typ -1*	External layer of plywood + PU adhesive Type-2 *Zewnętrzna warstwa sklejka+ klej PU Typ -2*	External layer of aspen + PVA adhesive Type-3 *Zewnętrzna warstwa osika+ klej PVA Typ -3*	External layer of plywood + PVA adhesive Type-4 *Zewnętrzna warstwa sklejka+ klej PVA Typ -4*
Moisture content *Wilgotność* (s; v, %), %	10.4 (0.354; 3)	10.2 (0.376; 4)	11.4 (0.370; 3)	11.0 (0.395; 4)
Density *Gęstość* (s; v, %), kgm^{-3}	332 (12.0; 4)	369 (12.5; 3)	317 (12.1; 4)	347 (13.2; 4)
Swelling in thickness *Pęcznienie* (s; v, %), %	1 (0.360; 39)	2 (0.264;16)	2 (0.685; 33)	2 (0.464; 27)
Tension strength *Wytrzymałość na rozciąganie* (s; v, %), Nm^{m-}2	0.458 (0.241; 54)	0.860 (0.356; 41)	0.783 (0.253; 32)	0.728 (0.198; 27)
3-point bending strength and modulus of elasticity *Wytrzymałość na zginanie 3-punktowe i moduł sprężystości podłużnej* (s; v, %), Nmm^{-2}	16.2 (3.11; 19) 4270 (190; 4)	19.8 (3.14; 16) 3700 (517; 14)	18.5 (1.68; 9) 4080 (275; 7)	16.6 (2.45; 15) 3300 (129; 4)
4-point bending strength *Wytrzymałość na zginanie 4-punktowe* (s; v, %), Nmm^{-2}	12.1 (1.30; 11)	16.2 (1.59; 10)	15.8 (2.09; 13)	14.3 (1.71; 12)

The comparison of some aspen cell board properties with common wood--based panel properties are presented in fig. 6, 7 and 8. Density values are given in fig. 6.

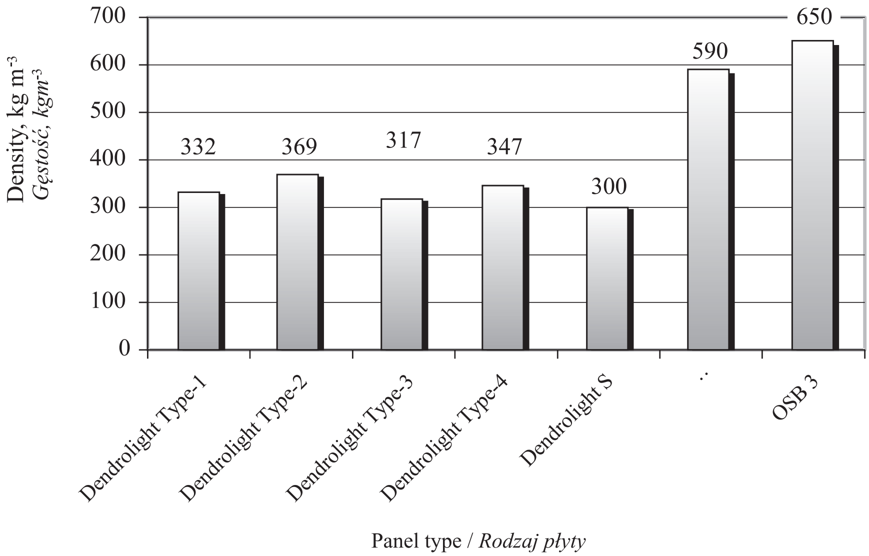

Fig. 6. Wood-based panel density
Rys. 6. Gęstość płyt drewnopochodnych

The average values of aspen cell panel properties were compared with the properties of 40 mm thick spruce cell panel covered with 3 mm thin spruce solid timber (Dendrolight S), 40 mm thick Swiss particleboard V20 (Particleboard), and 27 mm thick Kronoply OSB 3 oriented strand board (OSB 3). Aspen cell panels had higher density than spruce cell board, which it can be explained by the initial difference in density of both species. But all four types of aspen cell panels had considerably lower density than particleboard and oriented strand board.

The values of swellings in thickness after immersion in water for 24 h are presented in fig. 7. No significant differences were found in thickness swelling. After 24 hour immersion in water the thickness swelling was 2% or less for all four types of panels and it was equal to the thickness swelling of spruce panels covered with spruce. The acquired results were fivefold lover compared to particleboard and OSB 3. The density and thickness swelling parameters indicated that cell panels could be used as structural material.

Internal bond properties are presented in fig. 8. It can be seen that tension strength parallel to the plane of the panel of aspen cell panels was lower than the spruce cell panel tension strength. But still the results were twofold higher if compared with the values for particleboard or structural oriented strand board.

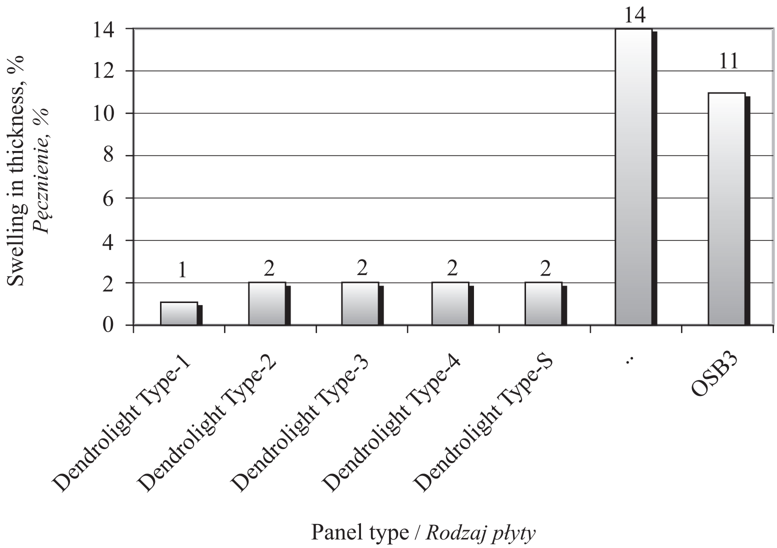

Fig. 7. Wood-based panel swelling in thickness
Rys. 7. Pęcznienie płyt drewnopochodnych

According to this initial research on aspen cell panel, aspen wood can be used as raw material for cell board production. Moreover, some aspen cell panel properties are comparable with or higher than those of frequently used structural wood-based panels.

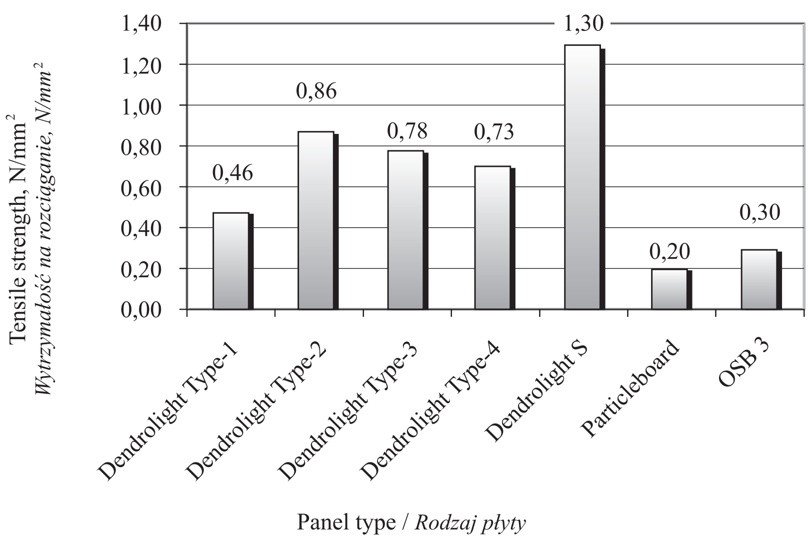

Fig. 8 Wood-based panel tensile strength
Rys. 8. Wytrzymałość płyt drewnopochodnych na rozciąganie

Conclusions

1. The difference in moisture content after conditioning was 1% on average when polyurethane adhesive DANA PU 2116 and polyvinyl acetate DANA-FIX 447 adhesive were applied in the production of aspen cell board panels. On comparing the influence of the external layer material on the moisture content of the panels, the results did not show significant differences between panels covered with birch plywood and aspen wood.
2. For both adhesives the highest density of the panels (358 kgm^{-3} on average) was achieved when birch plywood was used as the external layer material. Its density was 19% higher than that of reduced weight spruce panels with spruce external layer, but 20% lower than the average density of spruce solid timber. The lowest density (332 kgm^{-3}) was achieved when aspen wood was used as the external layer material for panels. Its density was 11% higher than that of spruce panels, but 30% lower than the average for spruce solid timber.
3. No significant differences were found in thickness swelling. After 24 hour immersion in water it was 2% or less for all four types of panels and it was equal to the thickness swelling of spruce panels covered with spruce.
4. The tensile strength perpendicular to the plane of the board was lower for all four types of panels compared with spruce panels covered with spruce (1.3 Nmm^{-2}), but for three types of panels (PU/P, PVA/A, and PVA/P) it was higher compared with spruce panels covered with veneer (0.65 Nmm^{-2}).
5. The 3-point bending test showed that the highest bending strength and modulus of elasticity occurred for aspen cell panels glued with polyurethane adhesive. The highest bending strength was reached for plywood covered panels (19.8 Nmm^{-2}), but the highest modulus of elasticity was obtained for aspen wood covered panels (4270 Nmm^{-2}). Other types of aspen cell board were characterised by significantly lower bending strength and modulus of elasticity.
6. For all four types of aspen panels the lowest 4-point bending strength was found when compared with reduced weight spruce panels covered with spruce wood (17.9 Nmm^{-2}), but all tests showed significantly higher bending strength when compared to reduced weight spruce panels covered with veneer (5.41 Nmm^{-2}).
7. According to this research aspen wood can be used for efficient production of reduced weight cell panels. Therefore, it is necessary to continue this research in order to define possible applications of the new material, even its use as a structural material.

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List od standards

LVS EN 310 2001. Wood-based panels; determination of modulus of elasticity in bending and of bending strength. Committee for Standardization, Brussels

LVS EN 317 2000. Particleboards and fiberboards - Determination of swelling in thickness after immersion in water. Committee for Standardization, Brussels

LVS EN 319 2000. Particleboards and fiberboards - Determination of tensile strength perpendicular to the plane of the board. Committee for Standardization, Brussels

LVS EN 322 1993. Wood-based panels - Determination of moisture content. Committee for Standardization, Brussels

LVS EN 323 2000. Wood-based panels - Determination of density. Committee for Standardization, Brussels

LVS EN 408 2003. Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties. Committee for Standardization, Brussels

PORÓWNANIE WŁAŚCIWOŚCI TRZYWARSTWOWEGO MATERIAŁU KOMÓRKOWEGO ORAZ PŁYT DREWNOPOCHODNYCH

Streszczenie

Płyty komórkowe o obniżonej gęstości mają szerokie zastosowanie w przemyśle meblarskim, wyposażeniu wnętrz, produkcji drzwi, środkach transportu. Mogą być również stosowane w wytwarzaniu płyt konstrukcyjnych. Założeniem badań było określenie przydatności drewna topoli (*Populus tremula)*, rozpowszechnionego na Łotwie, jako substytutu drewna świerku, w produkcji płyt o obniżonej gęstości. W badaniach wykorzystano: drewno topoli na warstwę środkową, trzywarstwową sklejkę brzozową na warstwy zewnętrzne oraz kleje poliuretanowe i polioctanowinylowe. Zbadano następujące parametry wytworzonych płyt: gęstość, wilgotność, spęcznienie, wytrzymałość na rozciąganie, wytrzymałość na zginanie i moduł sprężystości. W podsumowaniu stwierdzono, iż płyty komórkowe wytworzone z drewna topoli charakteryzują się podobnymi właściwościami fizycznymi i mechanicznymi jak płyty komórkowe wytworzone z drewna świerku.

Słowa kluczowe: drzewny materiał komórkowy, topola, płyta komórkowa