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THE PROPERTIES OF LIGHTWEIGHT STABILISED BLOCKBOARD PANELS

Lightweight Stabilised Blockboard (LSB) panel is a product newly introduced onto the market. Research was carried out to determine the main physical and mechanical properties of the panel and to evaluate the effect of panel direction and moisture content.

LSB panels have wide potential for application in the furniture industry, door production, transport, and construction board production. Potentially LSB panels are lighter, with lower density and higher form stability than solid wood and conventional fibreboard, particle board, oriented strand board (OSB) and plywood.

LSB panels produced from solid pine wood core and High Density Fibreboard (HDF) skins are found to have the following physical properties: average moisture content 8.6%; density 450 kg·m^{-3}; shrinkage coefficients 0.36% %$^{-1}$ for thickness and 0.25%·%$^{-1}$ for length and width; thickness swelling 6.3% after 24 hours' immersion in water. The following mechanical properties were determined: internal bond 0.51 N mm^{-2}; screw withdrawal resistance 1076 N from plane and 553 N from edge; bending strength 13.4 N mm^{-2}; and modulus of elasticity in static bending 1754 N mm^{-2}.

Keywords: Lightweight Stabilised Blockboard, physical-mechanical properties, high density fibreboard

Introduction

The production of timber building materials requires less energy than steel, concrete or plastic construction elements. When wood construction elements are used, they reduce the negative impact on air and water quality in the processes of production, utilisation and recycling [Labans 2016]. However, the reduction of costs of manufacturing, transporting, assembling and utilising wood furniture and building elements is an important factor both ecologically and economically. Several researchers [Voth 2009; Labans and Kalnins 2010; Skuratov 2010] have

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searched for new lightweight constructions for the furniture, transportation and building industries, paying attention to the cost-effectiveness of sandwich materials [Pflug et al. 2003]. One way to achieve this is to reduce the weight of various elements during the manufacturing process, modifying their structure by replacing high-density materials of the elements with lower-density material.

One such product is the Lightweight Stabilised Blockboard (LSB) panel, patented in Latvia by ARB Pope Ltd. This panel is made of Scots pine (*Pinus sylvestris* L.) solid wood boards and high density fibreboard panels. This combination can be called sandwich panels. The mechanical performance of sandwich panels depends mainly on the mechanical properties of the individual components from which they are built [Labans 2016]. For the LSB middle layer, double-sided longitudinal grooves cut in the sawn material make it approximately 40% lighter. LSB panel is obtained when these boards, in a 45° direction, are glued between two skins (usually high-density fibreboard panels). A significant influence of the relative humidity of the air and related moisture content of the panel on thickness swelling and internal bond properties was observed in this study. However, a change in relative humidity of the air and moisture content of the panel did not have an effect on the density and screw withdrawal strength properties of LSB panel. The panel direction was found to have a significant influence on both screw withdrawal strength and bending properties.

Several advantages of LSB panels may be highlighted in comparison with *DendroLight* [Iejavs and Spulle 2016] and conventional wood-based panels: manufacture is cost-effective due to a simplified production process; physical and mechanical properties of the panel in the length and width directions are identical, because of the panel's symmetry; thickness changes can be calculated from the shrinkage and swelling properties of solid wood and fibreboard. Due to the longitudinal grooves in the wood layer, internal stresses are reduced and the form stability of the panel is increased.

In some cases, reduced-weight Lightweight Stabilised Blockboard panels provide better or equivalent mechanical properties compared with conventional wood-based panels, for example OSB. The most important property of a cover material is the modulus of elasticity in tension and strength [Ashby 2004]. In the production of various construction elements, many products of sandwich panel type are well known: honeycomb structures for furniture and doors [Sandwich panels with cardboard core for furniture applications 2020]; the door panel from the German company Moralt [Wood based sandwich-type door panels 2020] and a new product called Diagonal Laminated Timber (DLT) [Production of the Diagonal Laminated Timber 2020]. Srinivasan [Srinivasan et al. 2007] and Banerjee and Bhattacharyya [Banerjee and Bhattacharyya 2011] have investigated the optimisation of lightweight sandwich panels with curved plywood in the core and skins. A modified version of hollow core sandwich panels with combined curved and straight vertical stiffeners has been investigated by Šliseris and Rocēns [Sliseris and Rocens 2013]. A wooden honeycomb panel was developed by Smardzewski [Smardzewski 2019]. In the present research, the properties of the newly developed wood product Lightweight Stabilised Blockboard (LSB) were investigated, leading to improved understanding of its suitability for particular applications.

Materials and methods

To produce LSB panels, mechanically graded solid pine (*Pinus sylvestris* L.) sawn materials of strength class C24 were used. The nominal dimensions of the sawn materials were 36 × 110 × 5000 mm, and they were dried to 12% moisture content. The end thickness of the LSB panels depends on the initial thickness of the sawn materials used. In addition to the mechanical strength grading, after visual assessment several significant defects were cut out from the lamellas: black knots with diameter larger than 15 mm, loose knots with diameter larger than 10 mm, knots with diameter larger than 30 mm, wane, bark and resin pockets.

After the removal of defects, finger jointing was carried out with polyvinyl acetate (PVAC) adhesive (water-based, white colour, glue line invisible after hardening, density 1.1 kg/l, pH approx. 3, solid residue approx. 50%, bond quality class D4 according to EN 204/205). Technical data of the finger joints were as follows: finger length 10 mm, finger pitch 3.8 mm, tip gap 0.6 mm. The finger joints were visible on the flat side of the lamellas. Figure 1 shows a schematic diagram of the manufacturing process of the LSB panels.

After finger jointing and planing, 2150 mm long planed boards with cross-sectional dimensions of 28 × 105 mm were obtained.

The next processing operation was longitudinal double-side groove cutting. The width of the grooves was 3 mm and the pitch 6 mm. The depths of the grooves were 5 and 18 mm. A cross-section of a board with grooves is presented in Figure 2.

These longitudinal grooves reduced the panel mass and density. When lamellas in a 45° direction were glued between two high-density fibreboard panels, an LSB panel was obtained.

A 6 mm thick HDF panel with dimensions of 2070 × 2800 mm was used for the LSB panel top layers. According to the manufacturer, the physical and mechanical properties of the HDF panel were as follows: density 800 $kg \cdot m^{-3}$; moisture content 6%; bending strength 23 $N\ mm^{-2}$; modulus of elasticity in bending 2700 $N\ mm^{-2}$. Thickness swelling reaches 17% after 24 h immersion in water. The mechanical properties of the HDF panel are significantly worse than those of birch plywood and solid pine wood, but significantly better than those of OSB and particle boards.

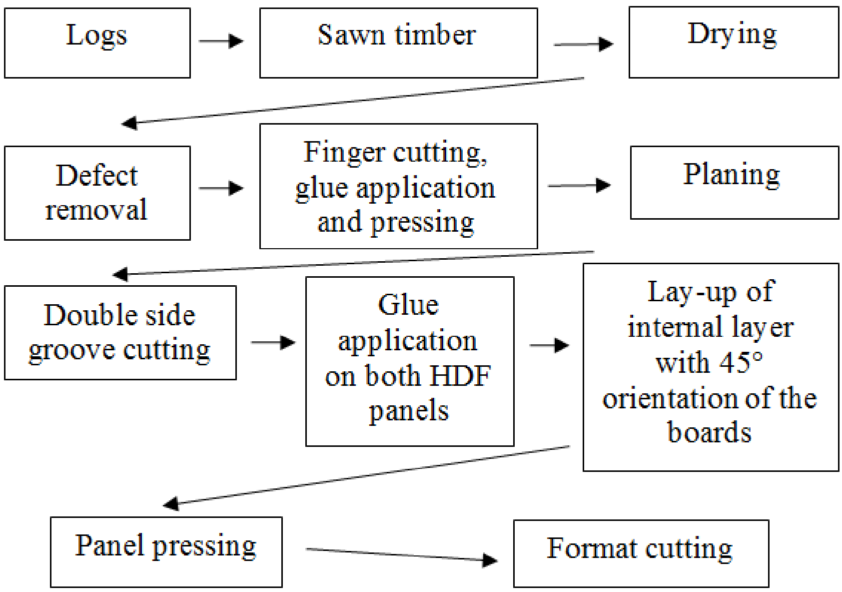

Fig. 1. Schematic diagram of the manufacturing process of LSB panels

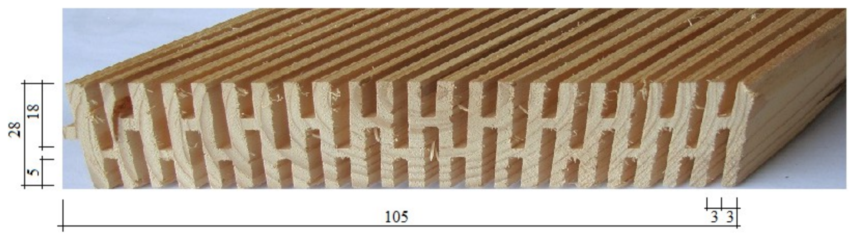

Fig. 2. LSB panel internal layer board profile: dimensions in mm

PVAC adhesive (mentioned above) was used to glue together the solid wood and HDF panels, with the following gluing parameters: pressure 0.2 N mm^{-2}; glue spread 180 g·m^{-2}; pressing time 60 min; temperature 20°C. The boards were oriented in a 45° direction against the longitudinal direction of the HDF panels, to achieve symmetry of the LSB panel in longitudinal and transverse directions. After the use of a pneumatic vacuum press, the final thickness of the LSB panel was 40 mm.

The final processing operation was panel format cutting, in which panels with nominal dimensions of 40 × 1220 × 2440 mm were produced.

In total, three full-size panels were used in the research. Figure 3 presents an LSB panel after format cutting.

Fig. 3. LSB panel with HDF external layers

The properties of the LSB panel were determined according to European standard testing methods widely used for the determination of the properties of conventional wood-based panels.

Because LSB panels and their products are planned mainly for use in indoor conditions, three pre-treatment conditions were used to evaluate the influence of relative air humidity and related panel moisture content on some physical and mechanical properties.

The pre-treatment conditions were defined as follows:

- reduced moisture content (30 ±5% relative humidity, 20 ±2°C temperature);
- standard climate (65 ±5%, 20 ±2°C); and
- elevated moisture content (85 ±5%, 20 ±2°C).

When a constant mass of the specimens was reached after each pre-treatment condition, the following properties of the panels were determined: moisture content according to the LVS EN 322:1993 standard; density according to LVS EN 323:2000; dimensional changes and related shrinkage and swelling coefficients according to LVS EN 318:2003; thickness swelling after 24 h immersion in water according to LVS EN 317:2000; internal bond according to LVS EN 319:2000; and screw withdrawal resistance (in both characteristic directions as shown in Fig. 4) according to LVS EN 320:2011. To determine the influence of specimen cutting angle on the bending strength and modulus of elasticity of LSB panels, the LVS EN 310:2001 standard was applied.

Because LSB panels are made from both solid wood and HDF panels, the equilibrium moisture content will differ. The structure and moisture content of an LSB panel may affect both physical and mechanical properties of the panel. In this research, several correlations were found between the main physical and mechanical properties of LSB panel and the moisture content and direction of the panel.

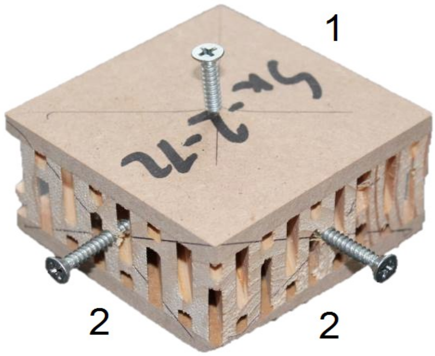

Fig. 4. Screw withdrawal resistance test specimen: 1 – from plane and 2 – from edge

Test specimens for bending strength and modulus of elasticity, cut in three different directions relative to the longitudinal direction of the panel, are presented in Figure 5. The difference is expressed as an angle between the length direction of the panel and the test specimen.

Fig. 5. Bending strength and modulus of elasticity test specimens: angle in degrees shows the deviation between specimen and panel length directions

Specimens for the bending test with 0° angle describe the properties of the panel as produced. Specimens with angles of 45° and 135° describe the stronger and weaker diagonals of the LSB panels.

Specifications of all test specimens used in the research are presented in Table 1.

Table 1. Specification of test specimens

Parameter	Test standard	Group No.	Specimen No., pcs.	Nominal dimensions mm	Relative humidity %
Moisture content W, %					
	LVS EN 322	3	12	40 × 50 × 50	30
			24		65
			12		85
Density ρ, kg·m^{-3}					
	LVS EN 323	3	12	40 × 50 × 50	30
			24		65
			12		85
Swelling in thickness after 24 h in water Ts, %					
	LVS EN 317	3	12	40 × 50 × 50	30
			12		65
			12		85
Shrinkage coefficient k_r, %·%$^{-1}$					
In thickness direction	LVS EN 318		12	40 × 50 × 300	30
In longitudinal direction		2	12		65
Swelling coefficient k_b, %·%$^{-1}$					
In thickness direction	LVS EN 318	2	12	40 × 50 × 300	65
In longitudinal direction			12		85
Internal bond I_b, N mm^{-2}					
	LVS EN 319	3	12	40 × 50 × 50	30
			12		65
			12		85
Screw withdrawal resistance F_{sk}, N					
From plane	LVS EN 320	3	12	40 × 75 × 75	30
			12		65
			12		85
From edge		3	24		30
			24		65
			24		85
Bending strength f_m and modulus of elasticity in bending E_m, N mm^{-2}					
0° direction	LVS EN 310	3	12	40 × 50 × 850	65
45° direction			12		
35° direction			12		

For the average values of all of the determined properties, standard deviations and coefficients of variation in % were determined. Correlation and regression methods were used to determine correlations between the investigated properties. The average values of the properties were compared using Student's t-test with a p-value approach, with a confidence level of 95%.

Results and discussion

The obtained average physical properties, standard deviations (SD) and coefficients of variation (COV) of LSB panels are presented in Tables 2 and 3.

Table 2. Physical properties

Parameter	Relative humidity of the air		
	30%	65%	85%
Moisture content *W* (SD; COV, %), %	5.51 (0.205; 3.76)	8.59 (0.191; 2.22)	13.7 (0.193; 1.41)
Density ρ (SD; COV, %), kg m^{-3}	442 (25.5; 5.78)	450 (25.9; 5.76)	445 (20.6; 4.63)
Thickness swelling T_s after 24 h immersion in water (SD; COV, %), %	7.8 (1.26; 16.2)	6.3 (1.04; 16.6)	5.2 (0.584; 11.3)

The moisture content increases on average by 8.2% (from 5.5% to 13.7%) after the relative humidity of the air increases by 55% (from 30% to 85%). Under standard climate, the average moisture content of the panels was 8.59%. The average moisture content of LSB panels is 2.6% higher than for HDF panels and approximately 3.4% lower than for solid pine wood, according to the literature [DIN 68100:1984]. The average moisture content of the LSB panel is 1.4% below that of the *DendroLight* type panel. The difference in moisture content can be explained by the difference in the thickness proportions of covered HDF and the middle layer wood in cross-sections of the *DendroLight* and tested panels.

Close positive correlations, with correlation coefficient r = 1, were obtained between air relative humidity and the moisture content of the LSB panels. Figure 6 shows a significant increase ($p < 0.05$) in moisture content related to the relative humidity of the air.

The average density values range from 442 to 450 kg·m^{-3}, and individual values vary from 402 to 494 kg·m^{-3} for all three pre-treatment conditions (Table 2). The average density of LSB panels was 10% lower than that of solid pine wood [Šķēle et al. 2002] and approximately 50% lower than the density of HDF panels [Bowyer et al. 2003].

According to the literature, the density of the *DendroLight* panel is directly dependent on the panel thickness. For example, the average density of a 25 mm thick panel made of cellular wood material covered with 4 mm HDF was 477 kg·m^{-3}, but for a 60 mm thick panel it was 385 kg·m^{-3}. Using the interpolation method, the density of a 40 mm thick *DendroLight* panel was calculated to be 438 kg·m^{-3}. This is only 3% lower than the density of a 40 mm thick LSB panel with 6 mm top layers.

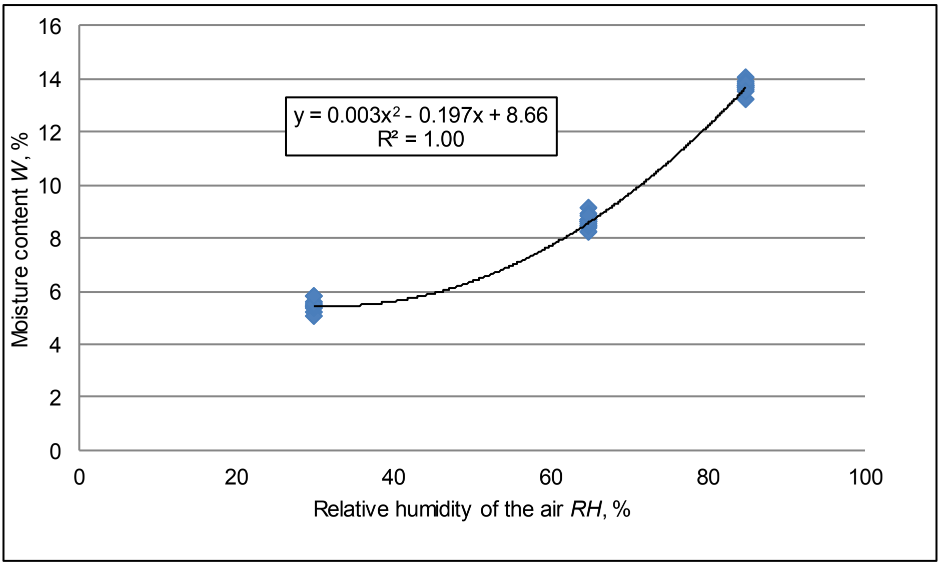

Fig. 6. The influence of relative humidity of the air *RH* on LSB panel moisture content *W*

According to the results of the research, an increase in air relative humidity from 30% to 85% and the related increase in the panel moisture content from 5.5% to 13.7% did not influence the average density of the LSB panels ($p = 0.72$). All data were obtained at a constant temperature of 20°C.

Thickness swelling properties after 24 h immersion in water decrease as the average initial moisture content of LSB panels increases. Thickness swelling decreased by 2.6% (from 7.8% to 5.2%) when the initial moisture content of the specimens increased from 5.5% to 13.4%. Thickness swelling data are presented in Table 1.

A moderately close negative polynomial correlation, with $r = 0.74$, was observed between the initial moisture content and thickness swelling properties of the LSB panels (Fig. 7).

Thickness swelling in *DendroLight* panels is directly dependent on the panel's thickness. For example, in 25 mm thick panels made of cellular wood material covered with 4 mm HDF, the average thickness swelling was 8.2%, but for 60 mm thick panels it was 3.6%. The thickness swelling calculated by the interpolation method for a 40 mm thick *DendroLight* panel after immersion in water was 6.2%. This is practically the same as for a 40 mm thick LSB panel with 6 mm top layers.

The shrinkage and swelling coefficients of the LSB panels are presented in Table 3. These coefficients are valid in an air relative humidity range from 30% to 85%. In the thickness direction the shrinkage coefficient was 15 times higher

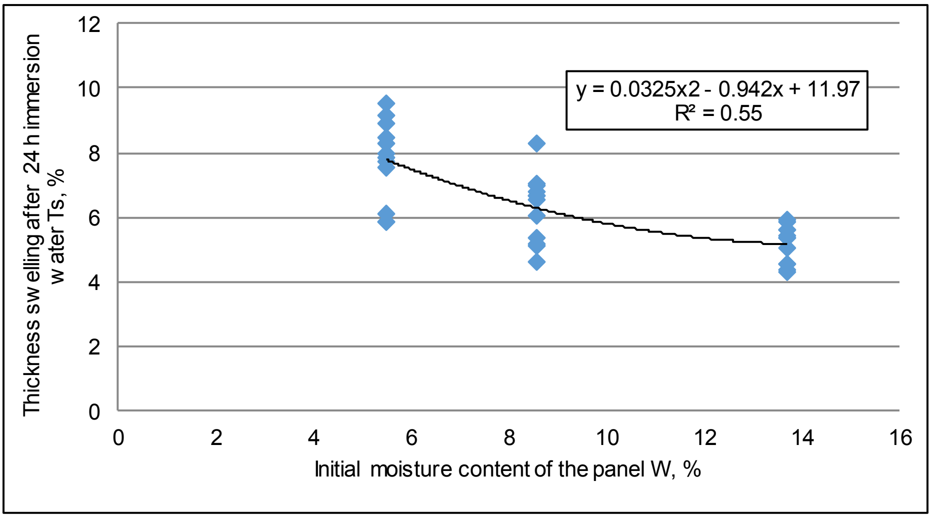

Fig. 7. The influence of the initial moisture content W on thickness swelling after 24 h immersion in water T_s of LSB panels

The shrinkage coefficient in the thickness direction of the LSB panel can be compared with the shrinkage coefficients of a conventional wood-based panel (plywood; OSB and particle board), which are from 0.3 to 0.7%·%$^{-1}$. In the panel's length and width directions the shrinkage coefficients are mainly lower than those of the conventional wood-based panel (from 0.02 to 0.05%·%$^{-1}$) [CEN/TS 12872:2007]. Data on the internal bond properties of the LSB panel are presented in Table 4.

Table 3. Shrinkage and swelling coefficients

Parameter	Relative humidity of the air		
	30%	65%	85%
Shrinkage coefficient in thickness direction k_{sh} (SD; COV, %), %·%$^{-1}$	0.361 (0.101; 27.8)		–
Shrinkage coefficient in length and width direction k_{sh} (SD; COV, %), %	0.0245 (0.00618; 25.2)		–
Swelling coefficient in thickness direction k_{sw} (SD; COV, %), %·%$^{-1}$	–		0.471 (0.0497; 10.6)
Swelling coefficient in length and width direction k_{sw} (SD; COV, %), %	–		0.0337 (0.00597; 17.7)

than in the length and width directions. The panel swelling coefficient in the thickness direction was approximately 14 times higher than in the length and width directions. This characteristic feature was taken into account when designing the panel, to decrease warping of panels in the length and width.

If we compare the internal bond of LSB panels after conditioning at 30% relative humidity and after conditioning at 65% relative humidity, no significant differences are observed ($p = 0.74$). After conditioning at 85% relative humidity, a significant decrease ($p < 0.05$) in the internal bond properties of the panel was observed. The data obtained correspond with those described in the literature, where it has been reported that an increase of up to 12% in the moisture content of conventional wood-based panels (for example OSB) significantly reduces the internal bond properties of the panel [Wu and Piao 1998].

Table 4. Internal bond and screw withdrawal resistances

Parameter	Relative humidity of the air		
	30%	65%	85%
Internal bond I_b (SD; COV, %), N mm^{-2}	0.510 (0.101; 19.9)	0.508 (0.0884; 17.4)	0.304 (0.0708; 23.3)
Screw withdrawal resistance from plane F_{sk} (SD; COV, %), N	970 (203; 20.9)	1076 (267; 24.9)	823 (180; 21.9)
Screw withdrawal resistance from edge F_{sk} (SD; COV, %), N	551 (98; 17.7)	553 (164; 29.6)	476 (77; 16.1)

The influence of moisture content on the internal bond strength of the LSB panels is presented in Figure 8. Close negative correlation ($r = 0.79$) was found between the moisture content and internal bond properties.

After pre-treatment of specimens in the standard climate, an average internal bond strength of 0.51 N mm^{-2} was obtained. This is approximately by 4-6% higher than the internal bond strength of the *DendroLight* panels. More significant differences were observed in comparison with OSB (0.3 N mm^{-2}) and particle board (0.4 N mm^{-2}). After all three pre-treatment conditions, for all internal bond test specimens, 100% failure between the HDF panel internal layers describes the failure mode of the LSB panels. The same failure mode was observed for *DendroLight* type panels with HDF external layers. The failure mode shows that the technological gluing parameters used in the research are optimal for covering pine boards with HDF panels.

The screw withdrawal resistance from the panel plane ranged from 614 to 1512 N. The average value of screw withdrawal resistance was 956 N for all three specimen pre-treatment conditions. The screw withdrawal resistance from the LSB panel edge was 55% lower on average (527 N), and ranged from 272 to 996 N (Table 4). The screw withdrawal capacity increases by more than 1000 N if the screw depth increases by more than 20 mm, but a different screw geometry must be chosen for that purpose.

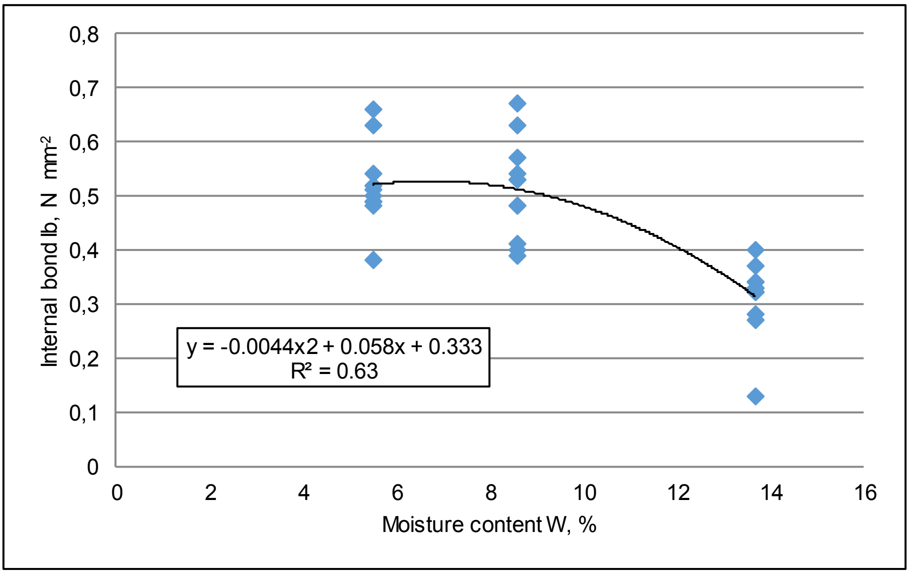

Fig. 8. The influence of the moisture content *W* on internal bond I_b of LSB panels

An increase in moisture content from 5.5% to 13.7% did not significantly influence the screw withdrawal resistance, since the observed correlations were weak.

No significant difference was found between the *DendroLight* panel and LSB panel in terms of screw withdrawal resistance. The values for the *DendroLight* panel ranged from 760 to 950 N when screws were withdrawn from the face, and ranged from 530 to 560 N when screws were withdrawn from the panel edge [DendroLight 3-layer panel – technical specification, 2020].

The results of the bending test show that the cutting angle of the specimen from the panel's longitudinal direction significantly influences the bending strength and modulus of elasticity values (Table 5).

The highest bending strength (26.4 N mm^{-2}) and modulus of elasticity in bending (3660 N mm^{-2}) were observed in the specimens cut at 45° (the longitudinal direction of the specimens matches the grain direction of the sawn materials). The lowest bending strength (9.56 N mm^{-2}) and modulus of elasticity (1432 N mm^{-2}) were observed for specimens made using an angle of 135° (the longitudinal direction of the specimens matches the transverse direction of the sawn materials). Average bending strength (13.4 N mm^{-2}) and modulus of elasticity (1754 N mm^{-2}) were obtained for specimens produced with a 0° angle.

Table 5. Results for bending strength and modulus of elasticity

Parameter	Specimen manufacturing angle		
	0°	45°	135°
Bending strength (SD; COV, %), N mm^{-2}	13.4 (1.59; 11.9)	26.4 (4.03; 15.3)	9.56 (1.65; 17.2)
Modulus of elasticity (SD; COV, %), N mm^{-2}	1754 (51; 2.90)	3660 (263; 7.19)	1432 (106; 7.38)

As presented in Figures 9 and 10, the angle used in the production of specimens significantly influences both the bending strength and modulus of elasticity of the LSB panels. In both cases close correlations were observed, with r = 0.94 in the case of bending strength and r = 0.98 in the case of modulus of elasticity.

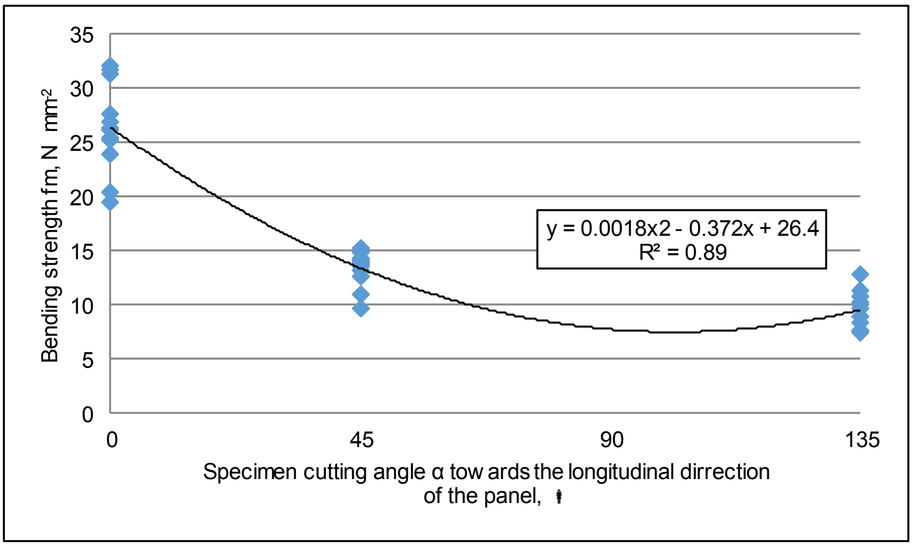

Fig. 9. The influence of the specimen cutting angle on the bending strength of LSB panels

When a product (such as a table top) is made with the same longitudinal direction as the LSB panel, the average bending strength (13.4 N mm^{-2}) and modulus of elasticity (1754 N mm^{-2}) may be used to calculate the load bearing capacity and deflection of the construction.

When the longitudinal direction of a product deviates by a certain angle from the LSB panel's longitudinal axis, the correlations shown in Figures 9 and 10 may be used for the prediction of bending strength and modulus of elasticity values.

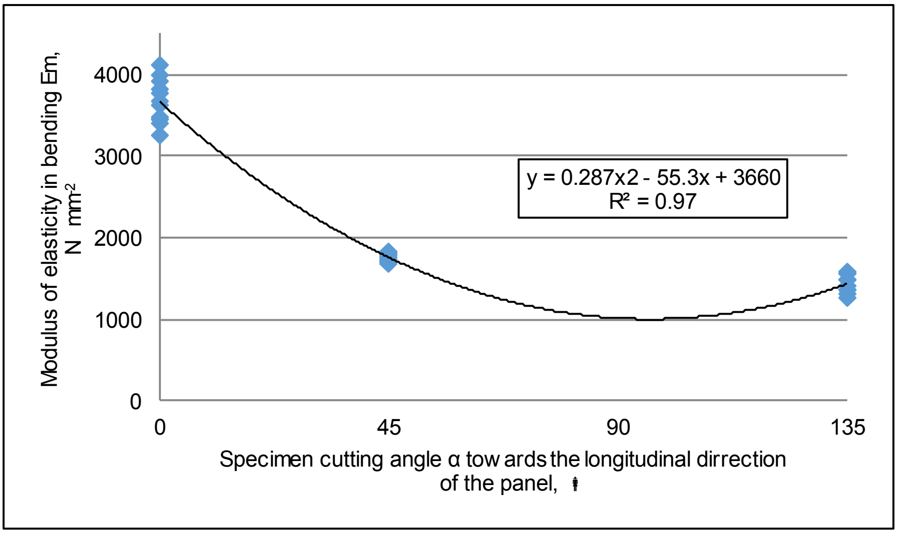

Fig. 10. The influence of the specimen cutting angle on the modulus of elasticity in bending of LSB panels

Bending strength calculated by the interpolation method for a 40 mm thick *DendroLight* panel in the longitudinal direction was 14.8 N mm^{-2}, and the modulus of elasticity was 1953 N mm^{-2}. In a transverse direction, the bending strength was 13.4 N mm^{-2} and the modulus of elasticity 1840 N mm^{-2}. In both cases the values of bending strength and modulus of elasticity of the *DendroLight* panel did not differ significantly from those of the LSB panel when the specimens were produced at a 0° angle.

For comparison, OSB bending strength ranges from 18 to 22 N mm^{-2} in a longitudinal direction and from 9 to 11 N mm^{-2} in a transverse direction. OSB modulus of elasticity ranges from 1400 N mm^{-2} in a transverse direction to 3500 N mm^{-2} in a longitudinal direction, at the average panel density of 650 kg·m^{-3}.

Due to the panel structure, in some cases LSB panels provide better physical and mechanical properties than conventional wood-based panels (such as OSB).

Conclusions

The average density of the LSB panels was 450 kg·m^{-3} after conditioning in the standard climate. Individual density values range from 402 to 494 kg·m^{-3} for a relative humidity range from 30% to 85%. The average density of the LSB panels is 10% lower than that of solid pine solid wood and approximately 50% lower than that of HDF panels. No significant difference in the average density values was observed between the LSB panel and *DendroLight* type panel.

There was a significant decrease in thickness swelling in the LSB panels on immersion in water (from 7.8% to 5.2%) after conditioning at high relative humidity, and the average moisture content of the LSB panels increased. Average thickness swelling (6.3%) was observed in specimens conditioned in the standard climate.

The shrinkage and swelling test showed that the LSB panel's thickness shrinkage coefficient ($0.361\%\cdot\%^{-1}$) is comparable to that of conventional wood--based panels, but in the length and width directions the shrinkage coefficient value ($0.025\%\cdot\%^{-1}$) is significantly lower.

No significant difference was found between the average internal bond strength values (0.510 and 0.508 N mm^{-2}) when the specimens were conditioned at 30% and 65% relative humidity. A significant decrease in the internal bond strength value (to 0.304 N mm^{-2}) was observed in specimens conditioned at 85% relative humidity.

The gluing parameters used in the research were optimal for the bonding of solid lamellas to high-density fibreboard panels, since failure of the specimens in all cases occurred in the middle layer of the fibreboard panel.

The average screw withdrawal resistance from panel edges (527 N) is 45% lower than the withdrawal resistance from the panel plane (956 N). An increase in the average moisture content of the panel from 5.5% to 13.7% did not influence the screw withdrawal resistance significantly. The screw withdrawal resistance values of the LSB panels are similar to those of the *DendroLight* type panels. For investigation of the screw withdrawal capacity of these types of materials, a modified testing method must be applied using a greater screw depth.

The bending strength and modulus of elasticity values of LSB panels depend on the cutting angle of the test specimens. When the panel's longitudinal direction matches the longitudinal direction of the specimen, average values of bending strength (13.4 N mm^{-2}) and modulus of elasticity (1754 N) were observed.

This research has shown that the physical and mechanical properties of the LSB panel are similar to those of the *DendroLight* panel. Due to the simplified manufacturing process of the LSB panels compared with the *DendroLight* panels, a significant reduction in production costs may be expected.

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LVS EN 310:2001 Wood-based panels. Determination of modulus of elasticity in bending and of bending strength
LVS EN 317:2000 Particleboards and Fibreboards. Determination of swelling in thickness after immersion in water
LVS EN 318:2003 Wood-based panels. Determination of dimensional changes associated with changes in relative humidity
LVS EN 319:2000 Particleboards and fibreboards. Determination of tensile strength perpendicular to the plane of the board
LVS EN 320:2011 Particleboards and fibreboards. Determination of resistance to axial withdrawal of screws
LVS EN 322:1993 Wood-based panels. Determination of moisture content
LVS EN 323:2000 Wood-based panels. Determination of density

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