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INVESTIGATIONS OF MECHANICAL PROPERTIES IN BENDING OF PARTICLEBOARD LAYERS*

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SYNOPSIS. Investigations of the elasticity modulus in bending and the bending strength of particleboards layers are presented. Three directions of the bending axis were considered: the direction of the mat forming, the direction perpendicular to it and the direction perpendicular to the board itself.

KEY WORDS: particleboard, face layer, core layer, modulus of elasticity, bending strength

INTRODUCTION

A three-layer particleboard consists of the central layer (core) and two outer layers (faces). The structures of these layers differ significantly. The faces are made of smaller chips whose resin content and compaction ratio are greater. As a result they have bigger density, stiffness and strength.

Mechanical properties of particleboard layers have not been sufficiently studied yet. The knowledge of these properties is necessary to make more rational projects of construction elements made of particleboard, among others in the stress analysis of these elements, especially in the joints. Moreover, it will make it possible to optimize the board structure and choose the right processing parameters (Kühne and Niemz 1980). The knowledge of elastic properties of particleboard layers will help to apply the layered systems bending theory for this board. This theory was first applied to particleboard by Keylwerth (1958), and its usefulness was confirmed by Bodig and Jayne (1982) and Hansel et al. (1988). It was later extended by Plath (1971) and then by Xu (1999). Using the so-called vertical

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density profile, they took into consideration the fact that the change in board density across its thickness was fluent and not stepwise. Experimental study of the profile influence on particleboard properties was carried out by WONG et AL. (1997).

Studies of mechanical properties of particleboard layers have been carried out in the Institute of Technology at Bydgoszcz University for a few years. An earlier paper by KOCISZEWSKI et AL. (2002) presented the results of experiments of bending properties of particleboard layers, considering only one axis of the bended test specimens, that is parallel to the direction of the mat forming of the board. This work takes a wider view of the problem taking into consideration the anisotropy of mechanical properties in bending of the board layers.

In particleboard three characteristic directions can be distinguished (Fig. 1): the direction of the mat forming of the board (x), the direction perpendicular to the mat forming of the board and tangent to the board (y) and the direction perpendicular to the board itself (z). The aim of the study was to determine the modulus of elasticity in bending, as well as bending strength of the face and the core of particleboard for the three bending axes: x, y, and z.

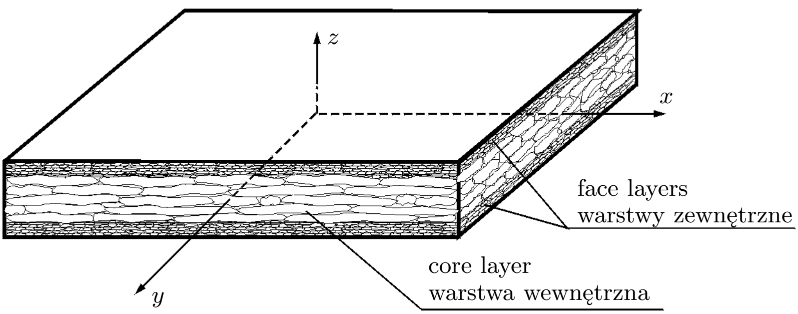

Fig. 1. Directions of three-layer particleboard: x – mat forming direction, y – perpendicular to the mat forming direction, z – perpendicular to the board plane
Rys. 1. Kierunki trzywarstwowej płyty wiórowej: x – kierunek formowania kobierca, y – prostopadły do kierunku formowania kobierca, z – prostopadły do płaszczyzny płyty

METHODS

A raw three-layer commercial particleboard meeting the requirements of EN 312-3 was used in the study. It was 18 mm thick, its density averaged 690 kg/m^3, and moisture content averaged 7%. Strips of layers were isolated from the board using appropriate mechanical processing. The face strips made of microchips were 2 mm thick and the core strip made of coarse chips was 12 mm thick. Mean density of the faces and the core was 930 and 590 kg/m^3 respectively.

The core test specimens with x- or y-axis were monolithic (Fig. 2) and the core samples with z-axis were glued using 12 mm thick layers (Fig. 4). The face test specimens with x- or y-axis were glued using 2 mm thick layers (Fig. 3) and the specimens with z-axis were glued in length using these layers (Fig. 4). Thirty samples for each kind of layer and the direction of bending axis were prepared. Both the modulus of elasticity in bending and the bending strength were fixed in accordance with the procedures specified in EN 310.

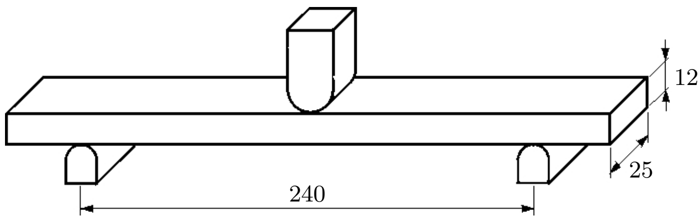

Fig. 2. Test specimen for determination of bending properties of the core layer for x- or y-bending axis
Rys. 2. Próbka do wyznaczania właściwości przy zginaniu warstwy wewnętrznej dla osi zginania x lub y

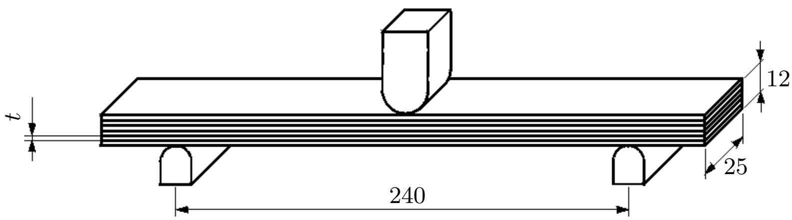

Fig. 3. Test specimen for determination of bending properties of the face layer for x- or y-bending axis, t – thickness of the face layer strip
Rys. 3. Próbka do wyznaczania właściwości przy zginaniu warstwy zewnętrznej dla osi zginania x lub y, t – grubość pasma warstwy zewnętrznej

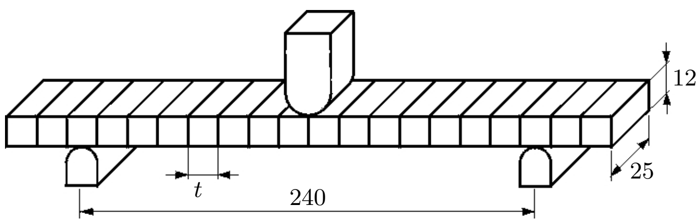

Fig. 4. Test specimen for determination of bending properties of the layer for z-bending axis, t – thickness of the layer strip
Rys. 4. Próbka do wyznaczania właściwości przy zginaniu warstwy dla osi zginania z, t – grubość pasma warstwy

RESULTS

The results – mean values and standard deviation for the modulus of elasticity and bending strength of the examined particleboard layers for the three directions of bending axis are shown in Table 1.

The first comparison of these values is between the face and the core (Fig. 5 and 6). The values of the face properties were assumed to be the basis for this comparison. For each direction of bending axis, both the modulus of elasticity and bending strength of the core are much smaller and range from 18.2 to 26.8% of the face properties. In other words the mechanical properties in bending of the core are approximately 4 times smaller.

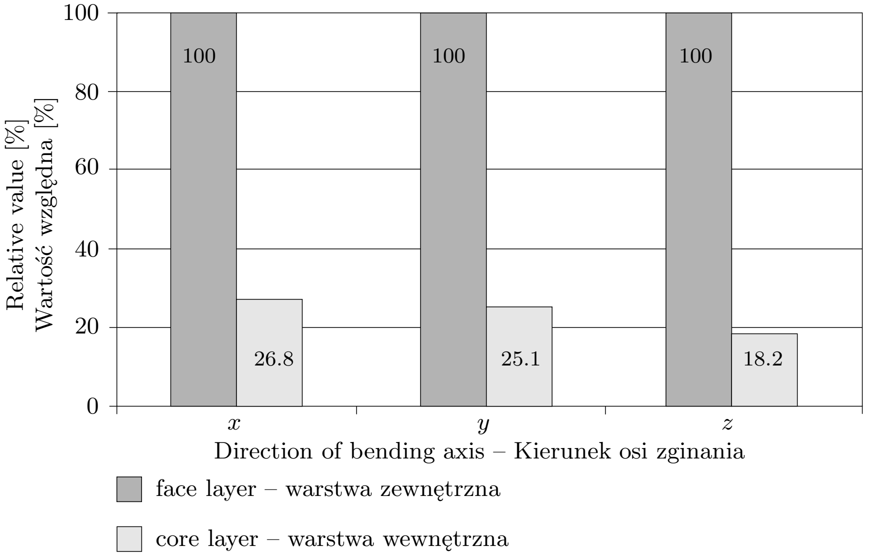

Fig. 5. Comparison of the elasticity modulus of the face and core layer
Rys. 5. Porównanie modułu sprężystości warstwy zewnętrznej i wewnętrznej

The second comparison refers to mechanical properties of the three directions of bending axis (Figs 7 and 8). The values of properties for x bending axis were assumed to be the basis for this comparison. It shows the anisotropy of mechanical properties in bending for the three directions of bending axis. For both the face and the core these properties in bending test specimens with y-axis are smaller than in bending those with x-axis. However, relative differences of these properties are rather small, ranging from 5.7 to 16.5%. The significance of differences of mean values of mechanical properties for x- and y-bending axis was evaluated (Table 2). These differences are in general statistically significant except the difference of mean values of bending strength of the face layer. In spite of it can be stated that the layer anisotropy in the plane of the board, specified by x- and y-axes, is low and assume that particleboard layers are approximately isotropic in their planes.

Table 1. Modulus of elasticity and bending strength of the face and core of tested particleboard for three directions of bending axis
Tabela 1. Moduł sprężystości i wytrzymałość na zginanie warstwy zewnętrznej i wewnętrznej badanej płyty wiórowej dla trzech kierunków osi zginania

Direction of bending axis Kierunek osi zginania	Modulus of elasticity in bending [MPa] Moduł sprężystości przy zginaniu [MPa]				Bending strength [MPa] Wytrzymałość na zginanie [MPa]			
	face layer warstwa zewnętrzna		core layer warstwa wewnętrzna		face layer warstwa zewnętrzna		core layer warstwa wewnętrzna	
	mean value wartość średnia	standard deviation odchylenie standardowe	mean value wartość średnia	standard deviation odchylenie standardowe	mean value wartość średnia	standard deviation odchylenie standardowe	mean value wartość średnia	standard deviation odchylenie standardowe
x	3 850	350	1 030	65	22.7	2.8	5.3	0.8
y	3 430	290	860	102	20.4	2.1	5.0	0.8
z	330	32	60	8	1.9	0.3	0.5	0.1

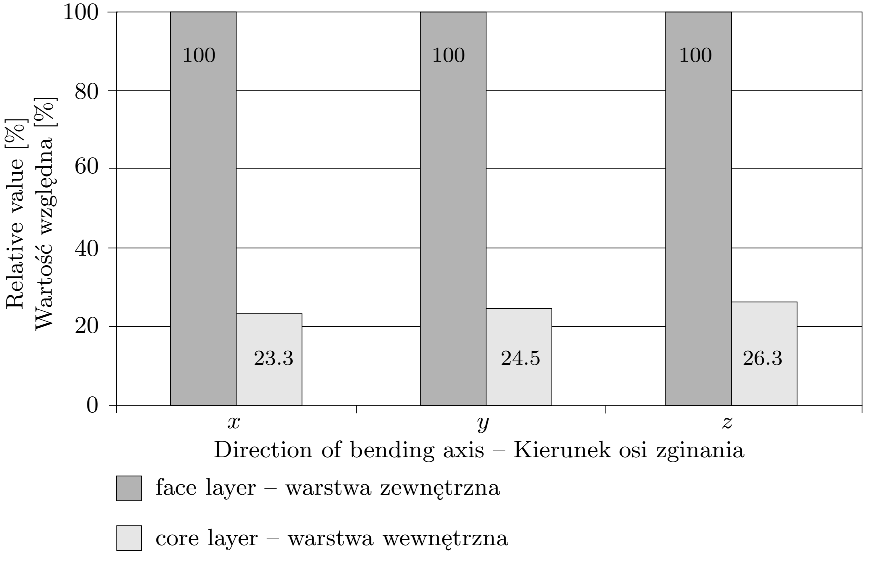

Fig. 6. Comparison of the bending strength of the face and core layer
Rys. 6. Porównanie wytrzymałości na zginanie warstwy zewnętrznej i wewnętrznej

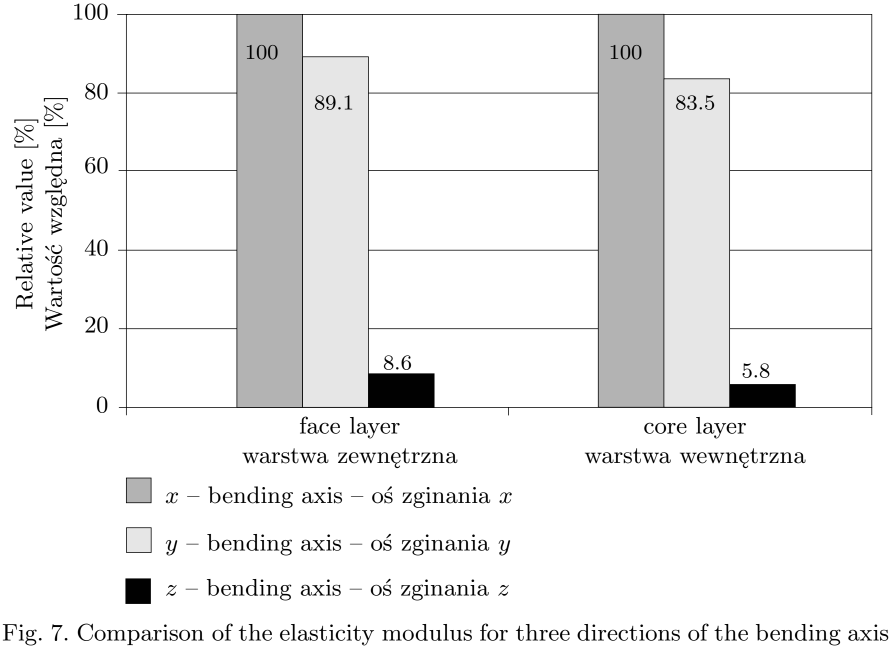

Fig. 7. Comparison of the elasticity modulus for three directions of the bending axis
Rys. 7. Porównanie modułu sprężystości dla trzech kierunków osi zginania

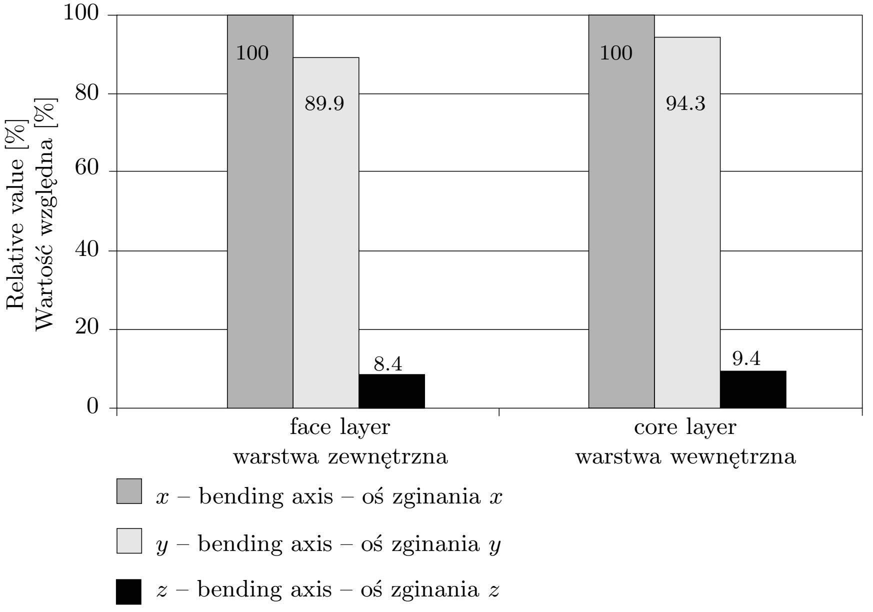

Fig. 8. Comparison of the bending strength for three directions of the bending axis
Rys. 8. Porównanie wytrzymałości na zginanie dla trzech kierunków osi zginania

The values of mechanical properties in bending test specimens with z-axis are, just as it was expected, very small. They range from 5.8 to 9.4% of those in bending test specimens with x-axis, which means they are over ten times smaller. The last comparison proves strong anisotropy of mechanical properties in bending of particleboard layers. Z-axis is perpendicular to the layers, and thus this strong anisotropy refers to the planes perpendicular to the layers.

CONCLUSIONS

1. The three-layer particleboard is characterized by sharp differentiation of mechanical properties of the face and the core.

2. The values of the modulus of elasticity in bending and bending strength of the core are approximately four times smaller than those of the face.

3. The layers of the board can be recognized as isotropic in the planes of these layers, mechanical properties in bending little depend on the direction of bending axis provided that the axis is in the plane of the layer.

4. The board layers show strong anisotropy in the planes perpendicular to these layers, the values of the modulus of elasticity and bending strength determined for the bending axis perpendicular to the layer are over ten times smaller than those determined for the bending axis parallel to the layer.

Table 2. Evaluation of significance of differences of mean values of mechanical properties for x- and y-bending axis
Tabela 2. Ocena istotności różnic wartości średnich właściwości mechanicznych dla osi zginania x i y

Compared property Porównywana właściwość	Value of Student's statistics Wartość statystyki Studenta		Significance of differences of mean values Istotność różnic wartości średnich
	calculated obliczona	critical* krytyczna*	
Elastic modulus of the face layer for x- and y-axis Moduł sprężystości warstwy zewnętrznej dla osi x i y	5.06	2.00	significant istotna
Elastic modulus of the face layer for x- and y-axis Moduł sprężystości warstwy wewnętrznej dla osi x i y	7.70	2.00	significant istotna
Bending strength of the face layer for x- and y-axis Wytrzymałość na zginanie warstwy zewnętrznej dla osi x i y	3.60	2.00	significant istotna
Bending strength of the face layer for x- and y-axis Wytrzymałość na zginanie warstwy wewnętrznej dla osi x i y	1.45	2.00	significant istotna

*For $30 + 30 - 2 = 58$ degrees of freedom and significance level $\alpha = 0.05$.
*Dla $30 + 30 - 2 = 58$ stopni swobody i poziomu istotności $\alpha = 0{,}05$.

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BADANIA WŁAŚCIWOŚCI MECHANICZNYCH PRZY ZGINANIU WARSTW PŁYTY WIÓROWEJ

Streszczenie

Przedstawiono badania modułu sprężystości przy zginaniu i wytrzymałości na zginanie warstw płyty wiórowej. Próbki do badań wykonano z pasm warstwy zewnętrznej lub wewnętrznej, odpowiednio wyciętych z płyty. Uwzględniono trzy kierunki osi próbek: zgodny z kierunkiem formowania kobierca płyty, prostopadły do niego i prostopadły do płaszczyzny płyty. Porównano właściwości warstw. Zarówno wartości modułu sprężystości, jak i wytrzymałości na zginanie dla warstwy wewnętrznej są około cztery razy mniejsze niż dla wykonanej z mikrowiórów warstwy zewnętrznej. Określono anizotropię badanych właściwości warstw. Jest ona nieznaczna w płaszczyznach tych warstw i bardzo silna w płaszczyznach do nich prostopadłych.

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