INFLUENCE OF THE VENEER QUALITY AND LOAD DIRECTION ON THE STRENGTH PROPERTIES OF BEECH PLYWOOD AS STRUCTURAL MATERIAL FOR FURNITURE

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ABSTRACT

Plywood is a widely used material in the construction of different furniture types. The production of seating furniture – chairs, armchairs, etc., has the highest share. Knowing plywood's properties is a prerequisite for its efficient use in the industrial production and improvement of the quality of consumer products. The objective of this study is to evaluate the influence of the veneer quality on the density, bending strength and modulus of elasticity of 20-21 mm thick plywood made of beech veneer.

The results showed that the veneer quality does not have an impact on the density, bending strength, and modulus of elasticity. Load direction under bending has a significant influence on the strength and deformation properties.

The results of this study will provide an opportunity for optimization of furniture construction made of beech plywood.

Key words: beech plywood, furniture construction, bending strength, modulus of elasticity, load direction in bending

INTRODUCTION

Plywood is widely used in contemporary furniture manufacturing. It is a relatively new material, which due to its qualities proves to be very versatile for both designers and manufacturers. Its specific properties determine its large share in the seating furniture manufacturing industry: chairs, armchairs, chaise lounges etc. Another sector where it is extensively used is the construction industry. Researching its deformation behaviour, studying its strength characteristics, and considering the impact of the veneer quality would contribute to the effective utilisation of plywood. Furthermore, the introduction of technologies which fully use natural wood resources with all its structural deficiencies is a priority since the deficit of high quality wood materials is becoming increasingly evident.

There is hardly any information in the specialized scientific literature in Bulgaria about any research on the strength characteristics and the deformation behaviour of plywood. Some data (Shishkov 1994) refer to research into different plywood types carried out in foreign laboratories without pointing out essential data about the type of adhesive and the thickness of the plywood panels. Panayotov et al. (2005) publish specific values of bending strength and modulus of elasticity in bending of parallel plywood without specifying the testing method and the direction of bending.

Foreign research in this area does not provide clear-cut information related to the physical and mechanical qualities and the deformation behaviour of this material. The greater part of the research explores plywood with big thickness of veneer layers (LVL) used mainly in the production of building panels. Research into the physical and mechanical characteristics and the modulus of elasticity of plywood is published by

Hrazsky and Kral (2005). The tests were carried out on foiled exterior plywood sheets of two types of construction with slip-resistant treatment. They tested combined plywood with plies with different thickness and all beech plywood. Higher values of the researched strength characteristics under loading of the test samples parallel to the layers were recorded in comparison to those under perpendicular loading. Also considerable dependence of the strength on density has been recorded.

Bal and Bektas (2012) studied the impact of wood type, the load direction and the type of adhesives on the strength and deformation behaviour of laminated plywood with 3 mm thickness of the veneer plies. They also confirm the essential impact of the density on the studied factors and established that all values of the bending strength and the modulus of elasticity are higher when the direction is perpendicular to the layers. The authors themselves define these results as a phenomenon, which they explain with the impact of pressure resulting from the pressing of laminated plywood during manufacture in a direction parallel to the veneer layers. The authors also specify that this tendency is typical in a large part of wood materials manufactured through hot pressing. Other researchers have come up with similar results (Daoui et al. 2011). They found out that the higher the thickness of the veneer layers, the higher the strength and deformation indicators perpendicular to the layers get. They also studied the impact of the quality of the veneer on the mechanical properties of plywood. The results of their experiment illustrate that the tendency toward lowering these qualities as the veneer thickness increases is limited and so is the impact of the surface roughness. The impact of the quality of the veneer in terms of the structural defects of the wood has not been estimated.

As it can be seen the results from the different researches suggest that the data in all studies vary and they are insufficient to determine unconditionally the strength characteristics of plywood. All this calls for determining specific and accurate values of strength and deformation characteristics of plywood, which would facilitate both scientific research on this relatively new material for furniture manufacturing, as well as help the manufacturers in the furniture industry.

MATERIALS AND METHODS

The research was done with test samples produced from two types of beech plywood of rotary cut veneer, manufactured by „Nikrom-Veneer“ Ltd, Petkovo. The first type of veneer has upper and inside layers of „A“ quality, referred to as „Series 1“, while the second one is with upper layers of „A“ quality and with inside layers of „BC“ and „C“ quality and is referred to as „Series 0“. The thickness of the plywood was 20 mm and 21 mm, respectively. Veneer panels were produced in size of 920 by 500 mm. Two-component urea formaldehyde adhesive manufactured by „DINEA“ – Hungary, with a quantity of 150 g/m^2 was used. Plywood manufacturing was carried out on „Vecciato VALTER“ multi-storey pressing machine. Pressing temperature was 110 ^oC, while the continuity was 15 min, and pressure was 1,3 N/mm^2.

The two types of plywood panels are cut out in order to produce test samples for testing their physical and mechanical properties. BDS EN 636 „Plywood: requirements“ are met. The sizes of the test samples were in accordance with BDS EN 310 „Wood based panels – Determination of modulus of elasticity in bending and bending strength“.

The results from the research into the two types of plywood establish the following physical and mechanical properties: density, modulus of elasticity and bending strength in two directions – perpendicular and parallel to the panel surface. These are key characteristics for determining the qualities of the studied materials.

The density was determined under a weight method through measuring the weight of a 50 x 50 mm test sample and thickness which corresponds to the thickness of the studied plywood. Electronic scales with 0,001 g accuracy were used.

The modulus of elasticity in bending and the bending strength are tested in accordance with BDS EN 310 „Wood based panels – Determination of modulus of elasticity in bending and bending strength" (fig. 1).

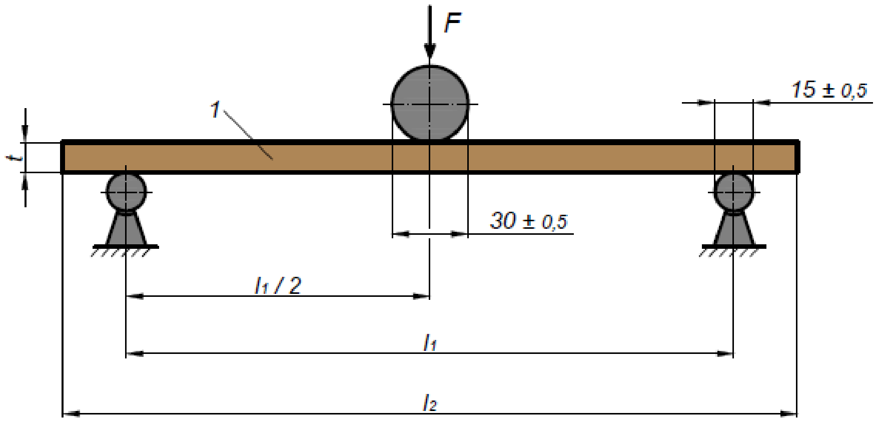

Figure 1: Testing method of panels to determine the modulus of elasticity in bending and bending strength perpendicular to the panel surface: 1 – test sample; F – load; t – thickness of the test sample; l_1 =20t mm and $l_2 = l_1 +50$. Dimensions are in mm.

Determining the modulus of elasticity and bending strength perpendicular to panel surface is accomplished through applying load in the middle of the test sample, attached to two fulcrums. The modulus of elasticity is calculated by using the linear part of the load-deformation diagram. The bending strength of each test sample is calculated as the ratio between the bending moment under destructive load and the resistance moment of the cross section.

The modulus of elasticity in bending E_m [N/mm^2] for each test sample is calculated using the formula:

$$E_m = \frac{l_1^3(F_2 - F_1)}{4bt^3(a_2 - a_1)}$$

where:

l_1 is the distance between the fulcrums' centers, mm;

b – the width of the test sample, mm;

t – the thickness of the test sample, mm;

F_2-F_1 – the difference between the upper and lower limit of loading the test samples in the straight part of the load-deformation diagram. $F_{1\ must}$ be approximately equal to 10 % and F_2 – approximately equal to 40 % of the destructive load, N;

a_2-a_1 – the difference in the measurements of the arrow of deflection in the middle of the test sample's length, corresponding to F_2-F_1, mm.

Bending strength f_m [N/mm^2] for each test sample is calculated using the formula:

$$f_m = \frac{3F_{max} l_1}{2bt^2}$$

where:

F_{max} is the destructive load, N;

l_1,*b* and *t*, are the same like in the modulus of elasticity, mm.

Determining the modulus of elasticity and the bending elasticity parallel to panel surface is done in the same way with the only difference being the size of the test sample and the load direction. The test samples have 20 x 20 mm nominal sizes of cross section.

RESULTS AND ANALYSIS

The data from the research carried out to evaluate the density, the modulus of elasticity and the bending strength are processed under the method of variational methods of statistics.

Table 1 contains the results related to the density of the studied 2 types of plywood panels. The data related to the density (760,1 and 755,6 kg/m^3) reveals that the results are close. The median values have minor differences of 0,59 % but it cannot be concluded that one has higher density than the other. This is supported by the Student's t-test according to which this difference is not statistically significant. Thus, the quality of the inside veneer layers does not impact significantly the density of plywood.

Table 1: Statistical data for the density of the tested plywood

Type of plywood		Series 1	Series 0
Number of test samples	number	20	20
Mean value	**kg/m^3**	**760,1**	**755,6**
Minimum value	kg/m^3	738,2	728,67
Median	kg/m^3	761,4	759,07
Maximum value	kg/m^3	784,6	768,58
Standard deviation	kg/m^3	13,36	10,34
Variational coefficient	%	1,75	1,37

Table 2 and figure 2 show the results related to the modulus of elasticity of plywood for the two types of loading.

Upon loading perpendicular to the veneer layers, the difference between the mean values of the modulus of elasticity in bending of the two series is 3,5 % with a higher value for Series 1. Upon loading parallel to the layers the difference is 4,5 % with a higher value for Series 0. These differences, however, do not give grounds for concluding either in favour of one or the other type of panel since according to Student's t-test the difference is statistically insignificant. Consequently, the quality of the veneer does not impact significantly the modulus of elasticity. The maximum value of 6949 N/mm^2 is recorded for Series 0 under loading parallel to layers.

Table 2: Statistical data for the modulus of elasticity in bending of plywood

Type of plywood		Series 1		Series 0	
		⊥	‖	⊥	‖
Number of test samples	pcs	26	22	18	19
Mean value	**N/mm^2**	**5286**	**6650**	**5107**	**6949**
Minimum value	N/mm^2	4874	6206	4839	6463
Median	N/mm^2	5253	6655	5098	6911
Maximum value	N/mm^2	5813	7204	5584	7411
Standard variation	N/mm^2	251	276	180	240
Coefficient of variation	%	4,74	4,16	3,52	3,45

The results related to the modulus of elasticity in bending, comparing the two different directions of loading, show a difference of 25,8 % for Series 1 and 36,07 % for Series 0. The difference between the mean values is statistically significant according to Student's t-test. All that gives grounds for concluding that for both types of plywood the obtained values for the modulus of elasticity in loading parallel to panel surface are higher.

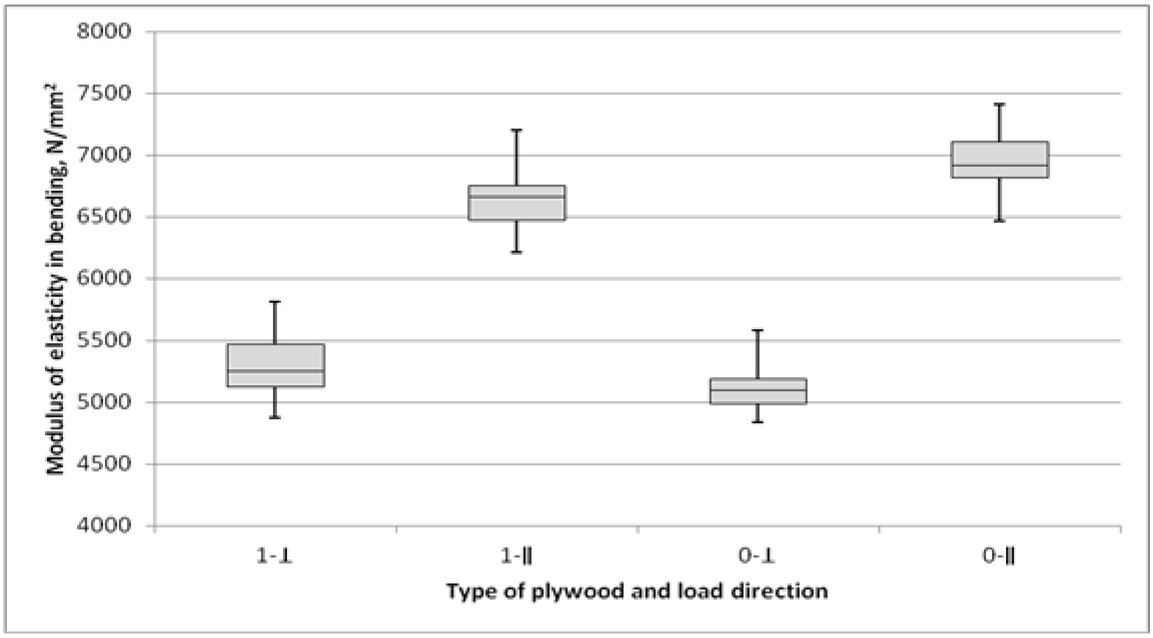

Figure 2: Modulus of elasticity in bending of two types of plywood under loadings perpendicular and parallel to the layers

Table 3 and figure 3 show the results for bending strength of plywood. The difference between the mean values for the two types of plywood under loading perpendicular to layers (55,58 and 53,38 N/mm^2), as well as under loading parallel to layers (63,16 and 63,17 N/mm^2) are minor and are statistically insignificant according to Student's t-test. When the values recorded under loading in the two different directions are compared, the differences are bigger (13,64 % and 18,34 %) and statistically significant.

Table 3: Statistical data for the plywood bending strength

Type of plywood		Series 1		Series 0	
		⊥	ǁ	⊥	ǁ
Number of test samples	number	20	20	18	18
Mean value	**N/mm^2**	**55,58**	**63,16**	**53,38**	**63,17**
Minimum value	N/mm^2	52,04	58,43	46,18	58,18
Median	N/mm^2	55,29	62,81	53,17	63,10
Maximum value	N/mm^2	60,35	68,26	60,21	68,30
Standard deviation	N/mm^2	2,28	3,04	4,85	2,56
Coefficient of variation	%	4,11	4,82	9,08	4,04

The destruction of the test samples under loading perpendicular to layers is caused in the most distant veneer layer. An exception to this rule are a few test samples (3,6 %) for which the destruction starts between the middle veneer layers, namely in Series 1. The most likely explanation can be that there are small areas with bad quality gluing between the individual layers. This can provide explanation for the slightly higher dispersion of the results in this test.

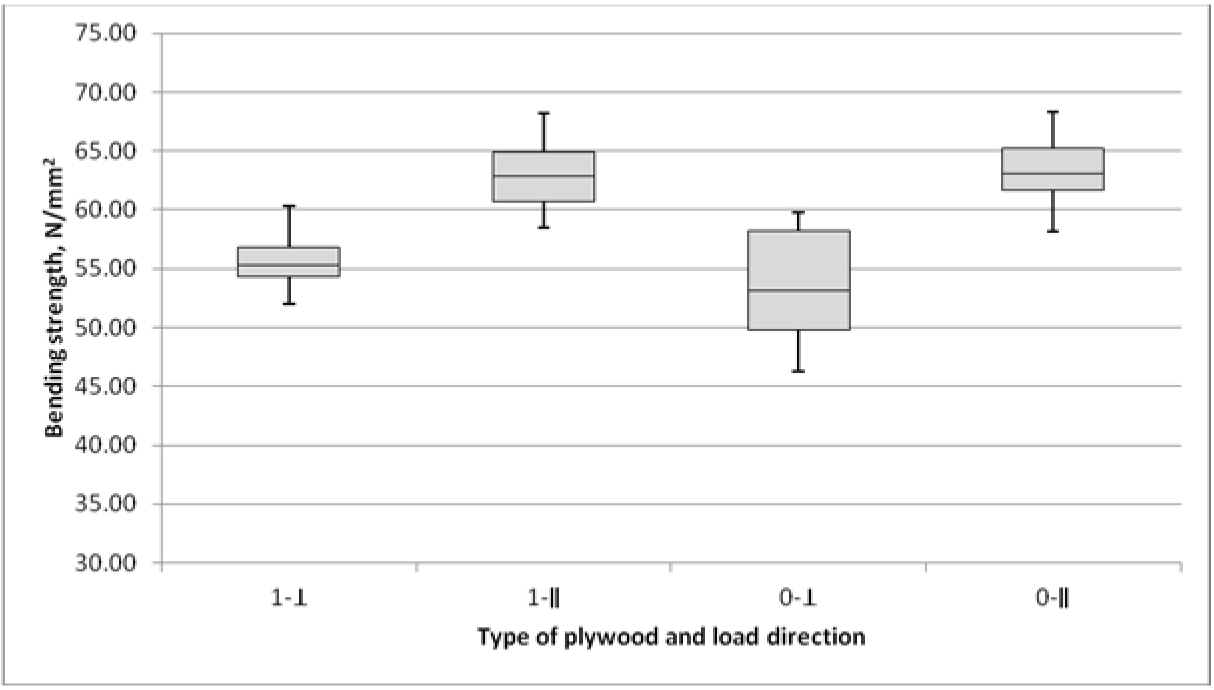

Figure 3: Bending strength of two types of plywood under loadings perpendicular and parallel to the layers

Under loading parallel to layers the destruction of the test samples is caused in the most distant to the pressing beam layer and splitting is observed in the larger part of the test samples.

CONCLUSIONS

The results from the experimental research aimed at determining the impact of the quality of veneer and the load direction on the strength and deformation characteristics of two types of beech plywood give reason to the following more general conclusions:

1. Using veneer of „BC“ and „C“ quality for the inside layers does not impact significantly the density, the modulus of elasticity in bending and the bending strength of the produced plywood.
2. The load direction has considerable impact both on the modulus of elasticity and the bending strength. Higher values are obtained when the loading direction is parallel to the panel layers. The difference obtained is between 14 and 36 %.
3. The two types of plywood can be categorized as classes of bending strength and modulus of elasticity F 30/40 and E 50/60 according BDS EN 636 „Plywood: requirements“.
4. The results can be used in strength design of the details or furniture constructions manufactured from plywood in order to optimize their cross section or to improve their strength.

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