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AN ANALISE BETWEEN THE MAIN PHYSICAL-MECHANICAL PROPERTIES OF THIN PLYWOOD.

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Abstract: The paper contain the comparatively analyze the main physical-mechanical properties of plywood with thicknesses between 1,0 and 6,0 mm: volumic mass, thickness, tensile strength parallel and perpendicular to the fiber, coefficient of elasticity to static and dynamic bending.
The research results were obtained in testing made on different indigenous species plywood that is beech, birch and alder, under industrial and laboratory conditions, in small size series.

1. INTRODUCTION

Wood species used to manufacture thin plywood must have such properties so to confer the following features:
- the possibility of un unrolling veneers with small thickness, 0.3 ÷ 0.6mm;
- special flexibility;
- increased strength to the action of the atmospherical agents;
- higher and rather constant physical-mechanical indices along all the directions: tensile strength (required to be above those of the other types of plywood), bending strength, shearing strength etc.
- planer surfaces with high strengths to loads.

Optimal wooden specia for manufacturing plywood in general and specialy for thin plywood are:

♦Birch *(Betula alba)*, wooden species traditionally used to manufacture thin plywood. In Romania, birch is spread in the northern part of the country (0,5% of the wooded area), from the Meridional Carpathians till Maramures.. The manufactured plywood presents superior features, such as: homogenous structure and small pores; tangential contraction coefficient of 0,4% for a 1% humidity variation, that is equal to that of beech wood; coefficient of elasticity to static bending higher than those of other broad-leaved tree wood; good capacity of cutting by unrolling; silky gloss;

♦Beech_*(Fagus sylvatica)* is the wooden species proposed as prioritary for the future manufacturing of thin plywood. This fact is justified by the great extent of beech forests covering, that is 42% in the total area of broad-leaved tree forests. In turn, these cover 76% in the total wooded area in our country. The spreading area for the beech is of 2 million hectars. Two million m^3 of logs are cut every year;

♦Alder *(Alnus glutinosa)* is a wooden species with small density and high capacity of cutting as thin veneers from which flat thin plywood can be manufactured. Alder wood has a homogenous structure and small pores; tangential contraction coefficient of 0,4% for a 1% humidity variation, that is equal to that of beech wood; coefficient of elasticity to static bending higher than those of other broad-leaved tree wood; good capacity of cutting by unrolling; silky gloss. The area covered by alder forests is small, that is why this is used only for special orders.

2. THE WORKING METHOD

Plywood boards were made under industrial and laboratory conditions, as follows:
- thin plywood manufacturing tests were made on industrial lines in company *SILVA-S.A.* and *Plywood Factory* within *ALPROM* Pitesti;
- thin plywood (0,3÷1,2 mm) were cut on unrolling or semi-unrolling machines in the factories where tests were made, as well as in *LOSAN* company;
- experimental technology took into account foreign norms content as well as experiments executed under laboratory conditions by researchers within *INL Bucharest;*
- the veneers intended for thin plywood were cut on a *CREMONA* type unrolling device that allowed the cutting of veneers with the lowest thickness of 0,3 mm. Cutting angular parameters used for thin veneers are presented in table 1[2].

Cutting angular parameters for thin veneers. Table 1

Angular parameters	***Wood species***	
	Beech, Birch	*Lime, Alder*
Knife sharpening angle	20°	16÷18°
Clearance angle	1÷2°	1÷2°
Cutting angle	21÷22°	17÷19°

From table 1 results that small sharpening angles were used; these allowed thin veneer unrolling; the clearance angle had as well small values to provide a good resting of the knife cutting edge in order to achieve low roughness surfaces.
- for thin veneers, 0.3÷0.5mm, film type adhesives were used; these allowed to use a suitable technology for veneer package and adhesive foil shaping while avoiding the adhesive leakage on the shaping support and achieving tego-type thin plywood (protected at the exterior with phenolic film);
- following the usage of new type of adhesive films based on phenolaldoformic resin, the values of the required pressures used to obtain a high quality glueing were much decreased, from 2÷2.5N/mm^2 recomended by the literature, to 0.6÷1.0N/mm^2 that provided a good gluing of the veneer sheets[7];
- the temperature of poly-condensation was 145÷147°C, while the time of poly-conden-sation was 3 minutes;
- time of pressing was chosen from diagrams depending on the temperature and structure thickness.

In order to establish the thin plywood properties standardized destructive methods were used as well as unconventional methods. Properties comparison methods were species and the content of the bedded structures. If possible, the comparison with other wood based boards was made under equivalent conditions [3]. The destructive tests were made according to the following standards:
- determining the strength and coefficient of elasticity to static bending: SR EN 310 / 1996
- determining teh volumic mass: SR EN 323 / 1996
- determining the tensile strength parallel to faces: STAS 1811/1971

The nondestructive were made to determine the coefficient of elasticity to dynamic bending (improperly called “the dynamic coefficient of elasticity to bending”), by using an original method proposed by the author. It consists in usage of acoustic emission (frequencies between 18-20.000 Hz) [3].

3. EXPERIMENTAL PLYWOOD STRUCTURES

The following plywood structures were accomplished:

a. 3-layers beech, alder and birch wood plywood with the following veneer thicknesses:
   - structure 1: 0,55 – 0,55 – 0,55 mm; g = 1,5 mm
   - structure 2: 0,65 – 0,65 – 0,65 mm; g = 1,8 mm
   - structure 3: 0,55 – 1,0 – 0,55 mm; g = 2,0 mm
   - structure 4: 0.65 - 1.20 - 0.65 mm; g = 2,4 mm
   - structure 5: 1,20 – 1,20 – 1,20 mm; g = 3,5 mm
   - structure 6: 1,20 – 2,50 – 1,20 mm; g = 4,8 mm

b. 5-layers birch and alder wood plywood with the following veneer thicknesses:
   - structure 1: 0,65 – 0,65 – 0,65 – 0,65 – 0,65 mm; g = 3,0 mm
   - structure 2: 0,65 – 1,20 – 1,20 – 1,20 – 0,5 mm; g = 4,8 mm
   - structure 3: 1,20 – 1,20 – 1,20 – 1,20 – 1,20 mm; g = 6,0 mm
   - structure 4: 0,65 – 1,20 – 2,50 – 1,20 – 0,65 mm; g = 6,1 mm

4. EXPERIMENTAL RESULTS

The obtained results are given in the tables 3 to 6.
The influence of the veneer layer number, structure veneer thickness, position and orientation of different structure thickness veneer on the plywood physical-mechanical properties stood out. The results presented in the below tables represent the arithmetic mean for more determinations on 6 test pieces[3].

Properties of 3-layer beech plywood. Table 2

Crt. no.	Plywood structure	Share of the layers having the same direction of the faces [%]	Thick-ness [mm]	Volumic mass [kg/m^3]	Tensile strength ‖ / ⊥ [N/mm^2]	Elasticity coefficient dynamic bending ‖ [N/mm^2]	Board dimensions
1	0,55-0,55 -0,55 mm	0,66	1,5	664	46/28	6326	1200x1000
2	0,65-0,65-0,65 mm	0,66	1,8	795	100/78	15164	1200x1000
3	0,55-1,0-0,55 mm	0,50	2.0	752	58/115	11964	1200x1000
4	0,65-1,20-0,65 mm	0.52	2.3	747	56/42	12040	1200x1000

Observation: as the beech structures thicknesses did not exceed 3 mm, the calculation of the elasticity coefficient to static bending (according to SR EN 310/1996) was not required.

Properties of 3-layer alder plywood. Table 3

Crt. no.	Plywood structure	Share of the layers having the same direction of the faces [%]	Thick-ness [mm]	Volumic mass [kg/m^3]	Strength to static bending ‖ / ⊥ [N/mm^2]	Tensile strength ‖ / ⊥ [N/mm^2]	Elasticity modulus to static bending ‖ [N/mm^2]	Elasticity modulus to dynamic bending ‖ [N/mm^2]
1	0,65-0,65-0,65 mm	0,66	1,80	650	22/18	51/16	5800	5880
2	0,65-1,20-0,65 mm	0,50	2,40	630	27/20	53/19	5650	5700
3	1,10-1,10-1,10 mm	0,66	3,00	615	29/18	51/38	5648	9513
4	1,25-1,25-1,25 mm	0,66	3,60	600	36/28	500/210	5640	5680
5	1,25-2,50-1,25 mm	0,48	4,90	580	41/34	480/220	5620	5660

Properties of 3-layer birch plywood. Table 4

Crt. no.	Plywood structure	Share of the layers having the same direction of the faces [%]	Thick-ness [mm]	Volumic mass [kg/m^3]	Strength to static bending ‖ / ⊥ [N/mm^2]	Tensile strength ‖ / ⊥ [N/mm^2]	Elastici-ty modulus to static bending ‖ [N/mm^2]	Elastici-ty modulus to dynamic bending ‖ [N/mm^2]
1	0,30-0,60-0,30 mm	0,50	1,00	619	-	76/36	-	8157
2	0,55-0,55-0,55 mm	0,66	1,50	743	-	92/86	-	10862
3	0,65-0,65-0,65 mm	0,66	1,80	680	-	68/36	-	6750
4	0,65-1,20-0,65 mm	0,55	2,40	670	29/22	69/45	6180	6730
5	1,10-1,10-1,10 mm	0,66	3,00	1178	31/28	84/56	6167	11640
6	1,25-1,25-1,25 mm	0,66	3,60	650	39/35	65/48	6150	6720
7	1,25-2,50-1,25 mm	0,48	4,90	650	46/41	63/52	6130	6700

Properties of 5-layer alder plywood. Table 5

Crt. no.	Plywood structure	Share of the layers having the same direction of the faces [%]	Thick-ness [mm]	Volumic mass [kg/m^3]	Strength to static bending ‖ / ⊥ [N/mm^2]	Tensile strength ‖ / ⊥ [N/mm^2]	Elasticity modulus to static bending ‖ [N/mm^2]	Elasticity modulus to dynamic bending ‖ [N/mm^2]
1	0,55-0,55-0,55-0,55-0,55 mm	0,66	2,50	710	36/28	74/51	5720	10456
2	0,65-0,60-0,60-0,60-0,65 mm	0,50	3,00	640	38/30	54/32	5880	6200
3	0,65-1,20-1,20-1,20-0,65 mm	0,50	4,80	620	46/44	52/48	5840	6120
4	1,25-1,20-1,20,-1,20-1,25 mm	0,72	6,00	605	48/44	510/420	5830	6110
5	0,65-1,20-2,50-1,20-0,65 mm	0,60	6,10	600	62/58	515/480	5840	6100

Properties of 5-layer birch plywood. Table 6

Crt. no.	Plywood structure	Share of the layers having the same direction of the faces [%]	Thick-ness [mm]	Volumic mass [kg/m^3]	Strength to static bending ‖ / ⊥ [N/mm^2]	Tensile strength ‖ / ⊥ [N/mm^2]	Elasticity modulus to static bending ‖ [N/mm^2]	Elasticity modulus to dynamic bending ‖ [N/mm^2]
1	0,55-0,55-0,55-0,55-0,55 mm	0,60	2,50	1007	41/36	88/96	690	10232
2	0,65-0,60-0,60-0,60-0,65 mm	0,50	3,00	700	45/38	72/52	7100	7900
3	0,65-1,20-1,20-1,20-0,65 mm	0,50	4,80	690	56/40	71/62	7120	7890
4	1,25-1,20-1,20-1,20-1,25 mm	0,72	6,00	670	88/55	88/60	7080	7830
5	0,65-1,20-2,50-1,20-0,65 mm	0,60	6,10	665	80/68	76/63	7060	7770
6	0,65-1,20-2,50-1,20-0,65mm	0,60	6,10	665	80/68	76/63	7060	7770

5. CONCLUSIONS

Analyzing the values presented in the above tables the following conclusions can be drawn:

♦**volumic mass** of thin plywood depends on:

-structure thickness, that is, as board thickness decreases the volumic mass increases. This is due to the phenomenon of partial densification, emphasized by the wood plasticization through the heat transmitting in the layers that come into contact with the heated pans;

-wooden species; the greatest values are met to the beech and birch plywood; the volumic mass of the alder plywood are lower with arround 40%;

♦**tensile strength** of thin plywood depends on:

-plywood thickness; as plywood thickness increases, tensile strength decreases;

-wooden species; most resistant on both loading directions are birch and beech plywoods;

-the share of veneer layers having the fiber direction perpendicular to the loading direction. For example, by comapring the values obtained for structures 1 and 3, 3-layer birch, to traction, cross loading, it is noticed that equal values for tensile strength were obtained although volumic mass of structure 3 is greater than that of structure 1. This fact is explained by the share of veneer layer having the fibers perpendicular to loading direction; for structure 1 this is 50% of structure 2 while for structure 3 it is 66%.

-number of veneer layers: as this number increases, parallel and perpendicular on fiber tensile strength values get closer, the plywood becomes more homogenous on the two perpendicular directions in the board plan (for example, 5-layer birch plywood structures)

♦**strength to static bending** depends on:

-face veneer thickness and the share of longitudinal in structure veneers; this is greater on longitudinal direction;

-veneer thickness increasing does not lead to a strictly proportional increasing of the bending strength perpendicular to face fibers; being placed in the middle of the structer the veneer contains the neutral line, while face veneer layers are stressed at maximum value.

-share of the layers having the same direction of fibres;

-strebgths to static bending are approximately equal on the two loading directions for the 3-layer plywood for which face layer share is about 17-25% in its thickness.

♦**coefficient of elasticity to static bending** did not present significant differences for different plywood structure thickness.

♦**coefficient of elasticity to dynamic bending** is with 2 – 10% greater than of static bending. This is because reologic properties of wood to dynamic loading, wood being perceived as more elastic material. For a static load part of elastic deformation becomes plastic deformation;

As a matter of fact, choosing the more appropriate plywood structure for a certain usage must be done in accordance to the stress that will load the structure, wood and adhesive properties.

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