Effects of the thickness of rotary-cut veneers on properties of plywood sheets. Part 2. Physical and mechanical properties of plywood materials

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ABSTRACT: The second part of the paper summarizes results of an institutional research aimed at the determination of physical and mechanical properties of different sets of plywood sheets pressed under different conditions. The first part dealt with the determination of compressibility or values of decreasing the thickness of pressed plywood sheets. In this second part, results are summarized of the analysis of physical and mechanical properties of the set of whole-beech plywood sheets of the nominal thickness of veneers amounting to 1.5 mm. The plywood sheets were manufactured as seven-ply and urea-formaldehyde resin DUKOL S was used for their production. The sheets were pressed using a pressure of 1.5 and 1.7 MPa. Following parameters were analyzed: moisture, density, bending strength, MOE in bending and shear strength.

Keywords: plywood; MOE in bending; bending strength; shear strength; moisture; veneer; statistical analysis

Wood is characterized by a number of excellent properties such as strength properties in relation to its density, heat insulation properties, good workability, etc. However, it shows also its drawbacks limiting possibilities of the full use of its advantages. It is not possible to manufacture materials of larger areas of wood without dividing it first to smaller parts and these parts to join subsequently to large-area materials. Wood does not exhibit sufficient hardness being anisotropic from the viewpoint of properties. It is subject to rot being not resistant to fire and water and contains various defects (knots, splits, checks).

Drawbacks mentioned above can be eliminated to a considerable extent or removed through wood processing to sheet or board materials. Larger dimensions can be achieved by the manufacture of peeled veneers and their subsequent pasting to large-area plywood sheets. The plywood sheets show broad use in various branches of human activities, viz. in furniture industry, building, manufacture of wraps, transport, agriculture etc.

Plywood sheets are defined as sheets with mutually pasted plies direction of fibres of neighbouring plies being perpendicular to each other. Generally, outer and inner plies on both sides are symmetrical with respect to the middle (or central) ply. For the manufacture of plywoods, quality raw material is used in sufficient lengths and diameters. It refers to the 2nd quality according to the ČSN 48 0055 and ČSN 48 0056 standards. The quality of plywoods is assessed according to many criteria and characteristics. Generally, it is possible to state that plywoods are classified according to valid standards. Plywoods have to fulfil requirements for dimensional accuracy (formats and dimension timber), gluing quality, outer quality features, physical and mechanical properties, special requirements of customers (decreased formaldehyde release, increased fire resistance, resistance to mildew, fungi and insect).

In plywood sheets manufactured from one species it is possible to create sheets with different strength properties in various directions by means of the combination of longitudinal and transverse veneers of various thickness. According to requirements of a final user it is possible to manufacture sheets with nearly identical properties in both directions (longitudinal, transverse) or sheets with markedly different properties in these directions.

Bending strength and modulus of elasticity in bending of plywood materials are affected by a number of factors, viz. wood moisture, wood density, wood structure, temperature, number of plies and permanent load.

Strength and elastic properties of wood and wood-based materials are dependent on moisture to the fibre-saturation point. Above the point they do not change any more. Within the range of moisture from 8 to 18%, changes in properties of wood and plywood sheets are most intensive being linear. With a change in moisture by 1% (in a range of 5–30%), bending strength changes by 4% and modulus of elasticity by 1% (Šteller 1978).

With increasing density modulus of elasticity in bending and bending strength increase. This relationship is expressed linearly. Relationships between density and mechanical properties of wood are more complex because wood strength is not dependent only on its density but also on its anatomical structure. Effects of density become evident particularly in dry wood whereas under conditions of wood moisture above the limit of hygroscopicity they are indistinct (Šteller 1967).

With increasing temperature, modulus of elasticity in bending and bending strength decrease. Effects of temperature on mechanical properties change with moisture. With increasing temperature and moisture wood strength markedly decreases. Parallel effects of both the factors lower the strength more than separate effects of each of the factors (Matovič 1993).

In bending load, the geometrical arrangement of plies acts a decisive role. Properties of particular plies and their proportion in the whole thickness of a sheet are an essential parameter. In elements loaded by bending it is possible to carry out extreme reduction of a middle ply (e.g. using honeycombs or foams) and thus it is possible to obtain relatively light combined sheets with high modulus of elasticity and bending strength. However, this reduction of the centre of sheets can result in problems concerning the application of the sheets, e.g. in fixing fittings (Poláčik 1979).

A dominant effect on properties of wood and plywood sheets (modulus of elasticity in bending, bending strength) is demonstrated by the angle of fibre direction between particular plies, kind of an adhesive and the proportion of a gluing mixture including the impregnation of plies by the glue for the purpose of compression and density (the degree of compression as compared with solid wood – Požgaj 1993).

Considerable effects are also shown by: tree species, wood quality, veneer thickness and the proportion of an extender in a gluing mixture. The kind of a glue then determines resistance to weather effects. Taking into account factors mentioned above properties of solid wood can be even exceeded.

As compared with solid wood, obvious homogenization has been achieved because defective places (knots, checks, etc.) are evenly distributed. A possibility to adapt anisotropy of plywood sheets to a certain construction function by the selection of a thickness profile is a great advantage of plywood sheets which cannot be achieved by competitive semi-finished products at all or only through a very exacting adaptation of the production technology. The producer of plywood sheets is, however, limited by directives on the permissible thickness of particular veneers.

Properties of whole-beech plywood sheets are the focus of great interest particularly in Germany. These sheets show a broad use particularly in furniture industry and in the construction of vehicles. A standard DIN 68 705 Teil 5: *Bau-Furniersperrholz aus Buche* prescribes minimum values for bending strength according to particular classes of categorization, i.e. according to a particular load. The standard also recommends veneer thickness ranging from 1.5 to 3.2 mm and prescribes the minimum number of veneers for particular thickness of plywood sheets.

Bending load occurs in a number of technical applications of plywood sheets, e.g. floors of vehicles, floors of podiums and exhibition areas, boards for formwork etc. The perfect knowledge of required values of bending strength for particular types of use makes possible to create plywood sheets of an optimum construction. Bending strength can be affected by various ways, e.g. using veneers produced from various tree species, by various thickness of veneers, direction of fibres, etc.

MATERIAL AND METHODS

An analysis of the effect of production parameters on changes in compressibility and physical and mechanical properties was carried out on the set of plywood whole-beech sheets of 1.5 mm veneer thickness and 10 × 2,575 × 1,335 mm dimensions. The plywood sheets were manufactured as seven-ply and urea-formaldehyde resin DUKOL S was used for their production.

Table 1. Mean values of moisture (%), density (kg/m^3), bending strength and MOE in bending (N/mm^2) of analyzed plywood sheets Nos. 1–12

Plywood No.	1	2	3	4	5	6	7	8	9	10	11	12
Moisture	7.96	8.37	8.46	8.68	8.50	8.63	8.77	8.40	8.44	8.55	8.64	8.72
Density	758.98	757.35	725.40	783.99	765.39	760.22	757.47	745.17	753.39	737.15	745.63	759.68
Longitudinal specimens												
Bending strength	96.33	85.91	91.48	89.02	94.44	91.85	86.19	85.32	98.01	93.33	109.83	98.28
MOE	9,695.86	8,139.34	8,657.52	9,447.27	8,985.91	8,889.50	8,993.06	9,338.45	9,112.83	8,870.74	8,835.12	8,928.57
Transverse specimens												
Bending strength	51.85	51.03	54.66	52.67	56.06	55.50	51.44	53.37	49.83	61.21	58.39	57.32
MOE	4,339.45	3,970.18	4,198.07	4,339.20	4,195.86	4,870.09	4,077.59	4,243.96	4,174.12	4,304.85	4,373.19	4,433.05

In the first part of the paper, results were summarized concerning thickness differences, extent of shrinkage, compressibility of veneers and the second part of the paper dealt with physical and mechanical properties of plywood sheets.

Within the study, twelve plywood sheets were pressed of a specific thickness and thus also specific physical and mechanical properties. The sheets were pressed using a pressure of 1.5 and 1.7 MPa. Determined values of particular properties were subsequently statistically analyzed.

For the manufacture of experimental plywood sheets veneers were selected according to a special methodology. This method of selection consisted in the measurement of values of thickness of particular veneers in predetermined places. Thickness was measured of both longitudinal and transverse veneers, namely in the same points. The average thickness of every veneer was evaluated statistically. Results were statistically classified from the smallest to the greatest average thickness. Moreover, veneers were assembled so that a plywood from the thinnest veneers to originate as the first one and in other plywoods (with a higher serial number) veneers of higher thickness to be gradually used. In these plywoods, thickness measurements were then carried out. The aim of the veneer thickness measurement was to determine effects of the various thickness of veneers on above-mentioned properties of pressed plywood sheets.

Measurements of thickness were carried out partly in moist newly peeled veneers and partly in veneers after drying. Within the study, veneer shrinkage was also determined in the course of a technological flow. Differences in the veneer thickness represent the tangential shrinkage of beech wood. The thickness of a plywood sheet was measured roughly 50 mm from edges. Five measuring points occur in one long edge, other two points in the other edge, thus there are in total seven measuring points (Fig. 1). The measurement was carried out accurate to 1% of thickness, at least to 0.1 mm.

In measuring and determining properties of sheets, the following ČSN EN standards were followed:
- ČSN EN 310. Boards of wood. Determination of the modulus of elasticity in bending and bending strength (in Czech). Český normalizační institut, 1995: 8.
- ČSN EN 314-1. Plywood sheets. Quality of gluing. Part 1: Testing methods (in Czech). Český normalizační institut, 1995: 12.
- ČSN EN 314-2. Plywood sheets. Quality of gluing. Part 2: Requirements (in Czech). Český normalizační institut, 1995: 8.
- ČSN EN 322. Boards of wood. Determination of moisture (in Czech). Český normalizační institut, 1993: 8.
- ČSN EN 323. Boards of wood. Determination of density (in Czech). Český normalizační institut, 1994: 8.
- ČSN EN 325. Boards of wood. Determination of dimensions of specimens (in Czech). Český normalizační institut, 1995: 8.
- ČSN EN 326-1. Boards of wood. Sampling, cutting and check. Part 1. Sampling, cutting test specimens and interpretation of the test results (in Czech). Český normalizační institut, 1997: 12.

Determination of bending strength and modulus of elasticity in bending was carried out by means of a testing machine ZD 10/90, manufacturer VEB TIR Rauenstein (Germany) with a measuring range of 0-2-4-10-20-40-100 kN.

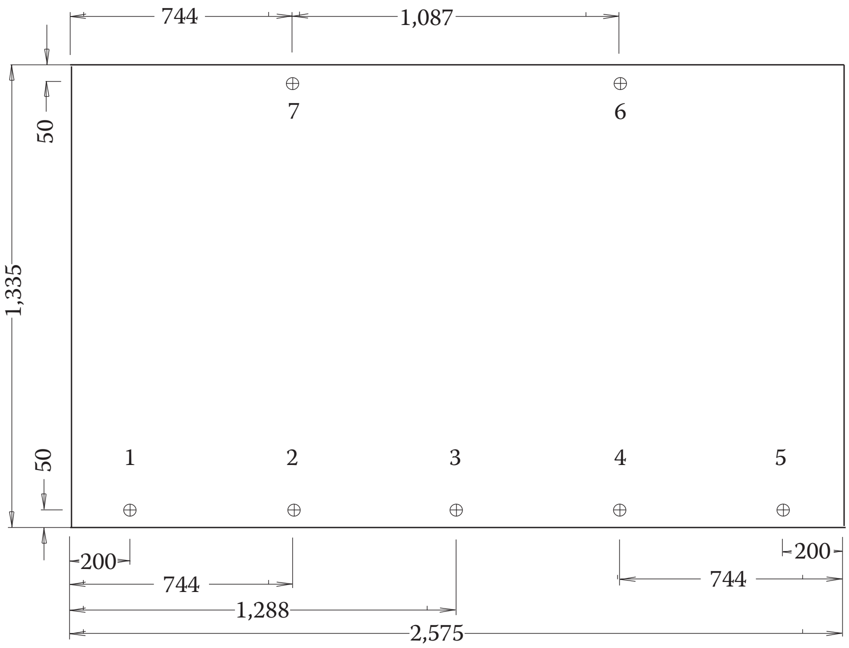

Fig. 1. Points of the measurement of veneer thickness

RESULTS AND DISCUSSION

Moisture of plywood sheets

Determination of moisture was carried out for the purpose of assessing plywood density because moisture can affect values of density. Moisture was monitored in twelve test specimens cut out from each analyzed plywood sheet. Data obtained were statistically processed (descriptive statistics). In Table 1 and Fig. 2, mean values of measured data are given for each plywood sheet.

The moisture of plywood sheets ranges from 7.96 to 8.77%. The smallest value was determined in plywood No. 1 (7.96%) and the greatest in plywood No. 7 (8.77%). The determined values of moisture agree with requirements of a standard.

Density of plywood sheets

Density was monitored in ten test specimens cut out from each of analyzed plywood sheets. Data obtained were statistically analyzed and determined mean values of moisture of particular plywood sheets are given in Table 1.

The content of the adhesive dry matter in the gluing mixture affects the plywood density. The plywood density is also dependent on the pressing power used. Higher pressure and smaller thickness of veneers substantially affect the density of plywood sheets. The smallest density was found in plywood No. 3 (725.4 kg/m^3). It is the result of the small thickness of particular veneers and low pressing power. In general, density corresponds with determined moisture. According to Table 1 and Fig. 2, plywood No. 1 shows the lowest moisture (7.96%) as compared with other sheets its density being 759.0 kg/m^3. The great increase in density in plywood No. 4 is also caused by the increase of its moisture. The growing course of density in plywoods Nos. 10, 11 and 12 is also induced by their growing moisture.

The density of a plywood sheet is related to its thickness. With the decreasing thickness of a ply-

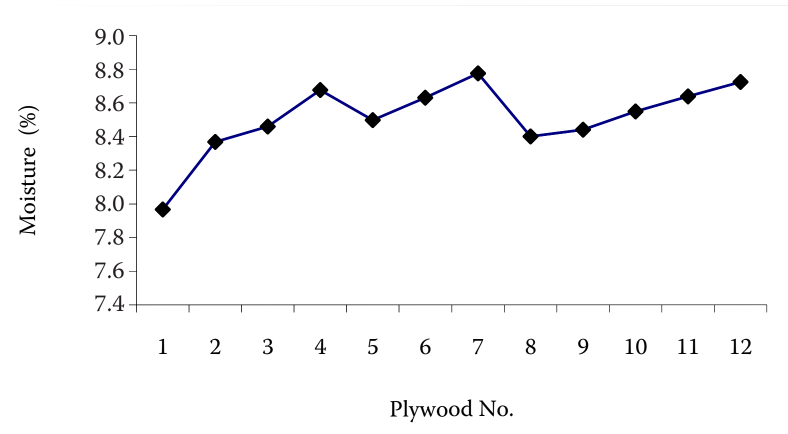

Fig. 2. Moisture of plywood sheets analyzed

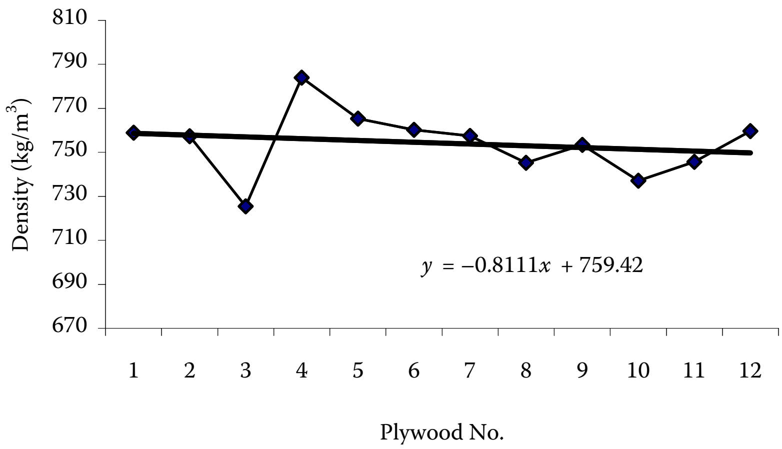

Fig. 3. Density of plywood sheets analyzed

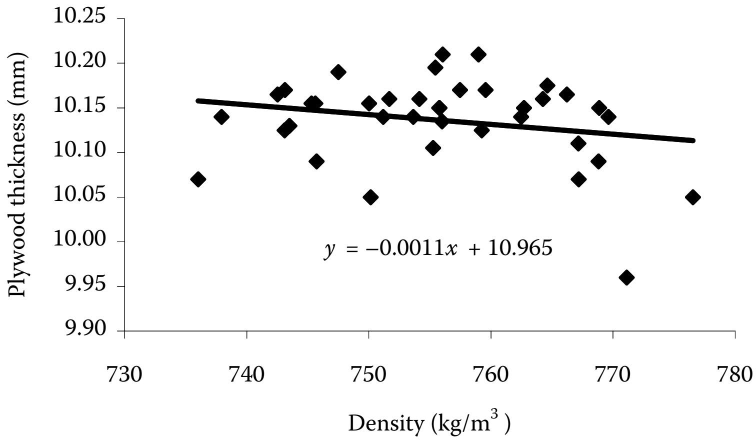

Fig. 4. Determination of the dependence of plywood sheet density on its thickness at a pressing power of 1.5 MPa

wood sheet its density increases. Fig. 4 shows the relationship at a pressing power of 1.5 MPa and Fig. 5 at a pressing power of 1.7 MPa.

Bending strength and modulus of elasticity in bending

Mean values of bending strength and modulus of elasticity in bending of analyzed plywood sheets Nos. 1 to 12 are given Table 1 and Figs. 6 to 9. Test specimens are differentiated cut out from sheets corresponding to the technological flow and across the technological flow (longitudinal and transverse specimens).

For both types of specimens minimum values are required of the limiting bending strength, viz.:

– transverse type 5 N/mm^2,
– longitudinal type 40 N/mm^2.

In analyzed plywood sheets, these mean values of bending strength were determined (Tables 3 and 5):

– transverse type 49.83–61.21 N/mm^2,
– longitudinal type 85.32–109.83 N/mm^2.

It follows that transverse specimens demonstrate as many as 12-times higher values of bending strength as compared with required values. In longitudinal specimens, minimum required values of bending strength are exceeded ca. 2 to 2.75-times.

Table 2. The strength of gluing plywood sheets

Arithmetic mean	Gluing strength in shear (N/mm^2)								
	2nd ply	4th ply	6th ply	2nd ply	4th ply	6th ply	2nd ply	4th ply	6th ply
	Sheet 1			Sheet 2			Sheet 3		
$\bar{x}$	3.25	3.42	3.66	3.85	3.87	3.73	3.29	3.19	3.48
	Sheet 14			Sheet 15			Sheet 16		
$\bar{x}$	3.24	3.16	3.04	3.61	3.40	3.87	3.41	3.63	3.26
	Sheet 17			Sheet 18			Sheet 19		
$\bar{x}$	3.16	3.26	3.22	3.04	3.54	3.34	3.69	3.73	3.25
	Sheet 110			Sheet 111			Sheet 112		
$\bar{x}$	3.29	3.86	2.95	3.52	3.20	3.53	3.47	3.33	3.23

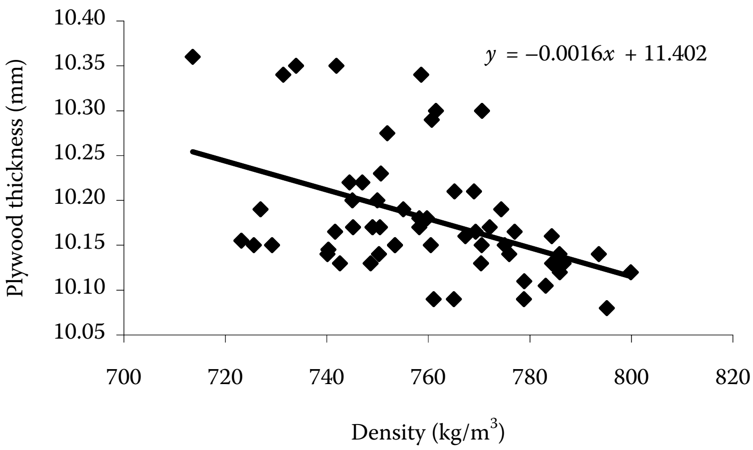

Fig. 5. Determination of the dependence of plywood sheet density on its thickness at a pressing power of 1.7 MPa

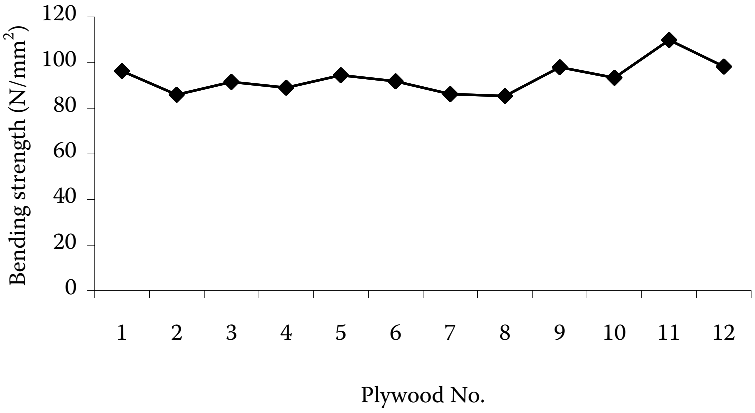

Fig. 6. Bending strength in plywood sheets – longitudinal specimens

As for longitudinal specimens, the highest mean bending strength is achieved by plywood No. 11, namely 109.83 N/mm^2. The lowest mean bending strength in longitudinal specimens is shown in plywood No. 8, namely 85.32 N/mm^2.

As for transverse specimens, the highest mean bending strength is achieved by plywood No. 10, namely 61.21 N/mm^2. The lowest mean bending strength in transverse specimens is shown in plywood No. 9, namely 49.83 N/mm^2.

As evident from Table 1, module of elasticity (MOE) in bending in both types show different tendencies. MOE in bending in transverse specimens grow with increasing thickness of a plywood (i.e. with increasing veneer thickness in a plywood). In longitudinal specimens, MOE in bending decrease with increasing thickness of a plywood. In longitudinal specimens, MOE in bending ranged between 8,139.34 N/mm^2 (plywood No. 2) and 9,695.86 N/mm^2(plywood No. 1). In transverse specimens, the module ranged between 3,970.18 N/mm^2 (plywood No. 2) and 4,870.09 N/mm^2 (plywood No. 6).

In all specimens, the determined bending strength was higher than the lower limiting value of 40 N/mm^2.

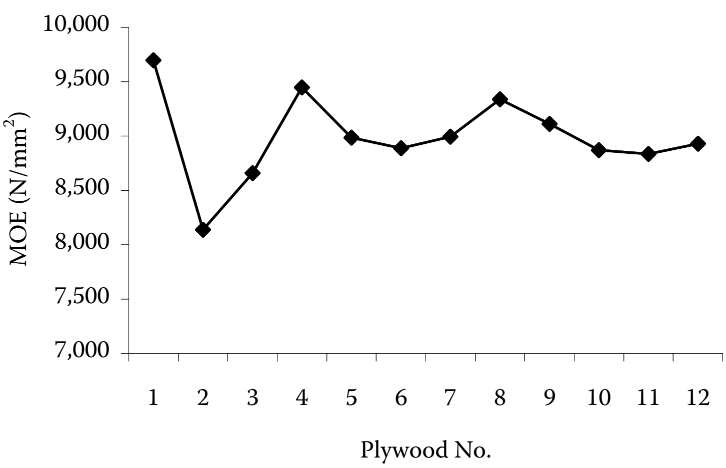

Fig. 7. MOE in bending of plywood sheets – longitudinal specimens

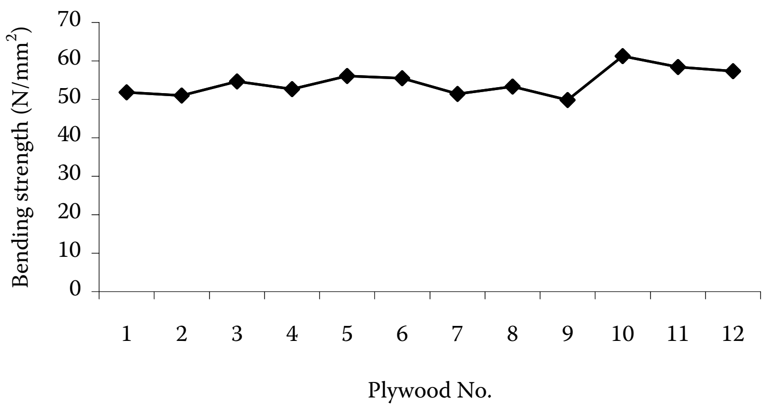

Fig. 8. Bending strength – transverse specimens

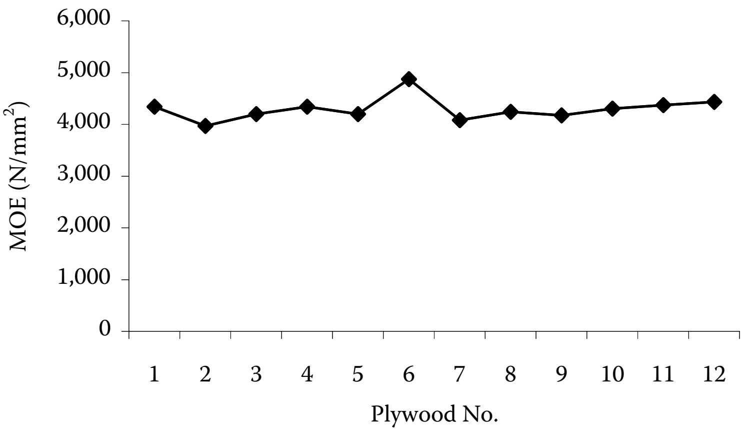

Fig. 9. MOE in bending – transverse specimens

The smallest bending strength is demonstrated by plywood No. 8 (85.32 N/mm^2), the highest one by plywood No. 11 (109.83 N/mm^2).

In longitudinal specimens, MOE in bending does not show an increasing trend. The course is unbalanced.

The smallest bending strength is demonstrated by plywood No. 9 (49.83 N/mm^2), the highest one by plywood No. 10 (61.21 N/mm^2). In all test specimens, the determined values were above the minimum required value of 40 N/mm^2.

Similarly MOE in bending in transverse specimens demonstrates nearly a constant course and only in plywood No. 6, a higher value was found, viz. 4,870.09 N/mm^2.

Fig. 10 shows the dependence of bending strength on the plywood thickness for longitudinal specimens. The figure indicates different behaviour of both sets. The first set is the set of plywood sheets pressed under the standard pressure of 1.5 MPa. The second set of plywood sheets was pressed under the higher working power of 1.7 MPa. In the set of plywood sheets, the dependence of bending strength on the plywood thickness demonstrates a decreasing tendency. In sheets pressed under a standard pressure, the dependence of bending strength on the plywood thickness shows an increasing trend.

Fig. 11 depicts the dependence of MOE on the thickness of plywood sheets in longitudinal specimens. Both sets show nearly the same behaviour (the first one

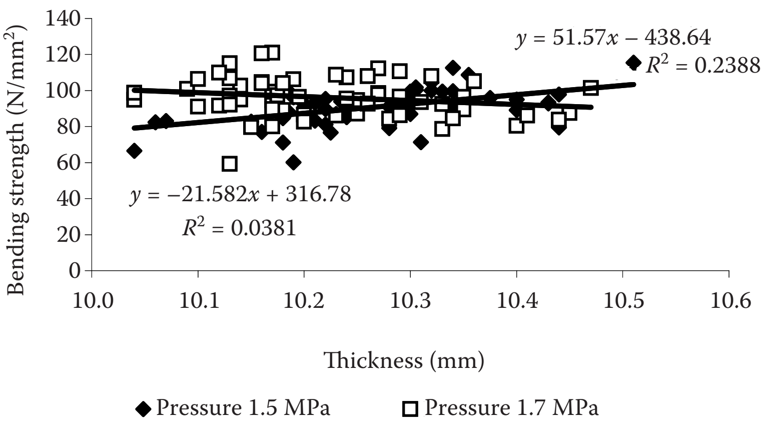

Fig. 10. Dependence of bending strength on the plywood thickness – longitudinal specimens

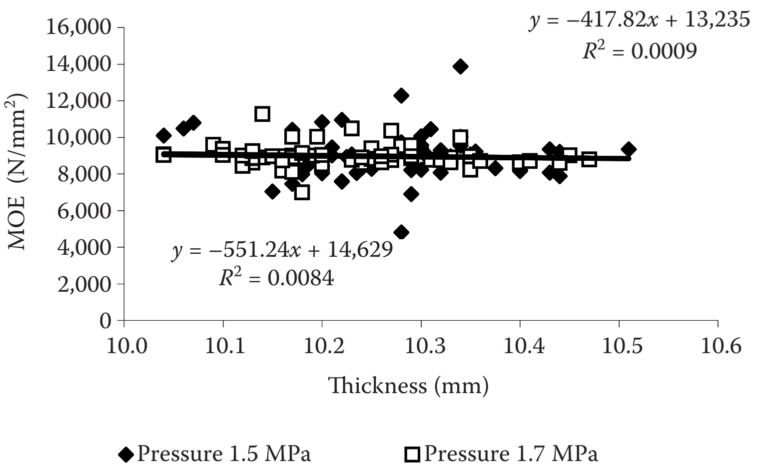

Fig. 11. Dependence of MOE on the plywood thickness – longitudinal specimens

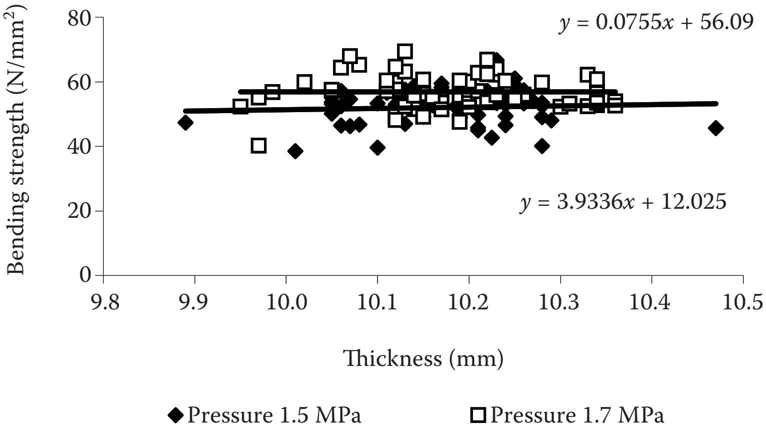

Fig. 12. Dependence of bending strength on the plywood thickness – transverse specimens

pressed using a working power of 1.5 MPa, the second one pressed using a working power of 1.7 MPa).

Fig. 12 depicts the dependence of bending strength on the thickness of plywood for transverse specimens. A higher increasing tendency is evident in the set of plywoods pressed under a standard pressing power. In the set of plywood sheets pressed under an increased working pressure, higher mean values of bending strength were achieved.

Fig. 13 depicts the dependence of MOE on the thickness of plywood sheets in transverse specimens. The higher increase in MOE values is visible in the set of plywood sheets pressed under an increased working pressure. In sheets pressed under a standard pressure, the MOE trend is decreasing.

The strength of gluing plywood sheets

The strength of gluing plywood sheets Nos. 1–12 (shear strength) is given in Table 2 and Fig. 14. The gluing strength was tested in specimens with sections to the second, fourth and sixth veneers (plies).

The various thickness of veneers and pressed plywood sheets does not effect the shear strength of

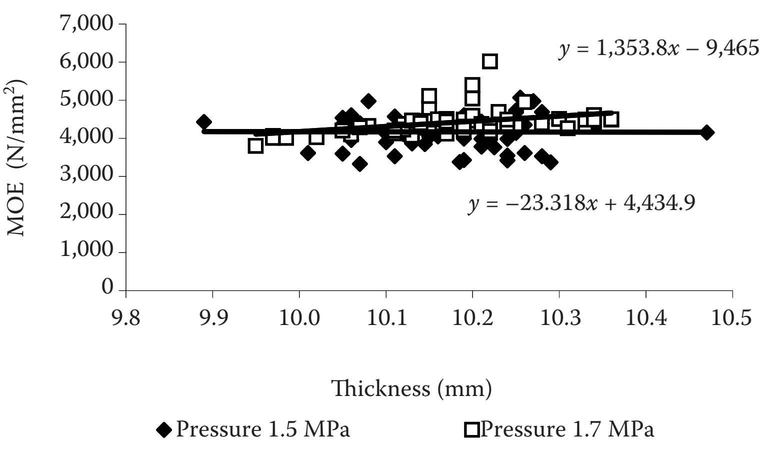

Fig. 13. Dependence of MOE on the plywood thickness – transverse specimens

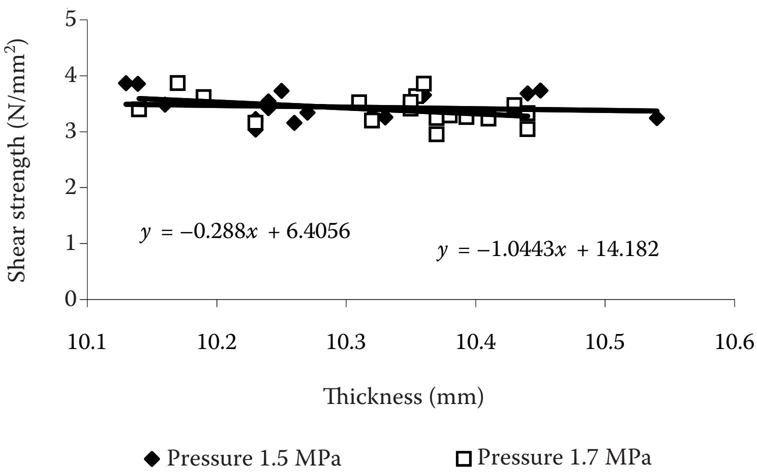

Fig. 14. The dependence of shear strength on the thickness of plywood sheets

gluing. Even under various production methods, i.e. in using a lower pressing power (1.5 MPa) and an increased pressing power (1.7 MPa), a substantial effect on the behaviour of the sets did not occur. Correlation coefficients in sets pressed using working powers 1.5 and 1.7 amounted to 0.12226 and 0.38106 (correlation between bending strength and the sheet thickness). Thus, neither correlation value is statistically significant.

SUMMARY

Different sets of plywood sheets of a specific construction and thus also different physical and mechanical properties were assessed. The thickness of special-purpose veneers was measured in predetermined places and the veneers were sorted from the lowest to the highest thickness. Sets of veneers were composed in such a way that the first plywood consisted of the thinnest and the last one from the thickest veneers. Thus, the thickness variability of a set originated which was subsequently analyzed.

Owing to the higher pressing power of 1.7 MPa, the coefficient of compressibility increased ranging from 7.15 to 11.21% (see the 1st part of the paper, Journal of Forest Science, *51*, 2005, No. 9: 403–411). The thickness of particular veneers decreased by 0.112 to 0.186 mm.

The density of plywood sheets increased with the increasing pressing power. Values of density ranged between 725.4 and 784.0 kg/m^3 (Table 1).

Bending strength was studied in two types of test specimens, viz. longitudinal and transverse. According to the ČSN EN 310 operative standard, the minimum value of bending strength amounting to 5 N/mm^2 is set for transverse bodies and for longitudinal bodies 40 N/mm^2. In analyzed specimens, these minimum values were exceeded. In transverse specimens, the mean bending strength ranged from 49.8 to 61.2 N/mm^2 and in longitudinal specimens from 85.32 to 109.83 N/mm^2.

The highest mean value of MOE was determined in plywood No. 1, viz. 9,695.86 N/mm^2. The smallest value of MOE was determined in plywood No. 2, viz. 8,139,34 N/mm^2.

In transverse test specimens, the highest MOE value was found in sheet No. 6, viz. 4,870.09 N/mm^2 and the smallest one in sheet No. 2, viz. 3,970.18 N/mm^2.

The bending strength in longitudinal specimens pressed using a working power of 1.5 MPa showed an increasing trend with the increasing thickness of a plywood. For longitudinal specimens pressed using a working power of 1.7 MPa a decreasing trend in strength was found with the increasing thickness of a plywood sheet. Transversal types of specimens pressed under 1.5 MPa showed the same behaviour as sheets pressed under 1.7 MPa, i.e. demonstrated a slightly increasing trend in bending strength.

Higher average values of bending strength were achieved in plywood sheets pressed under 1.7 MPa as against sheets pressed using a working power of 1.5 MPa.

The average shear strength (gluing strength) was mostly higher than 3 N/mm^2 in the second, fourth and sixth plies and thus, a requirement for the value of a minimum shear strength was achieved in all specimens. In specimens pressed using an increased working power of 1.7 MPa, higher shear strength was achieved. All analyzed plywood sheets fulfilled required values of bending strength, MOE and shear strength.

CONCLUSION

The paper summarizes results of an institutional research in the field of evaluating and assessing wood-based composite materials. The aim of then paper was to analyze dimensional reduction of veneers in their manufacture and subsequently after pressing to finished plywood sheets. Changes in properties of veneers and plywoods were evaluated, viz. thickness differences, shrinkage, moisture and density in relation to changes of parameters during production. In pressed plywood sheets following parameter were studied: bending strength, MOE and gluing strength by a shear test.

Assessing the properties of analyzed sets of plywood sheets has proved that with decreasing the thickness of veneers in a plywood sheet the coefficient of compressibility increases.

MOE and bending strength in plywood sheets are decisively affected by the proportion of longitudinal and transverse veneers in the sheet construction. Through the combination of the veneers it is possible to produce sheets of required parameters. The fact shows a critical importance for the economic optimum use of wood in the construction of plywood sheets. Plywood sheets pressed of veneers with negative thickness tolerance can bring a higher economic effect caused by the application of a lower pressing power. In consequence of the use a higher pressing power of 1.7 MPa, it is possible to achieve higher bending and shear strength but values required by a standard can be also achieved using a lower pressing power of 1.5 MPa.

Economic benefits can be achieved by the production of sheets from the thinnest veneers. The thickness of the thinnest sheet amounted to 10.16 mm (No. 1) and the thickness of a sheet with the highest average thickness amounted to 10.39 mm (No. 7). The sheet was pressed using a lower pressure of 1.5 MPa. Sheet No. 1 was manufactured from veneers of a mean thickness of 1.56 mm. In sheet No. 7, the mean thickness of veneers amounted to 1.62 mm. A difference in thickness between sheets 1 and 7 amounted to 0.06 mm. It means that 3.75% material saving was achieved between the sheets.

Further research will be the follow-up of the paper. The research will be aimed at the evaluation of using other composite wood-based materials in relation to physical and mechanical properties. An objective of the study will be creation of the new construction of a plied composite material with higher usable properties under conditions of minimized production and material costs.

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Vliv tloušťky loupaných dýh na vlastnosti překližovaných desek. Část 2. Fyzikální a mechanické vlastnosti překližovaných materiálů

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ABSTRAKT: Článek shrnuje výsledky institucionálního výzkumu zaměřeného na stanovení fyzikálních a mechanických vlastností překližovaných materiálů. Článek navazuje na část 1. – Slisovatelnost překližovaných materiálů, ve které bylo pojednáno o slisovatelnosti neboli zmenšení tloušťky lisovaných překližovaných desek. Posouzení vlivu tloušťky a tloušťkových tolerancí použitých dýh na hodnotu slisovatelnosti a fyzikálních a mechanických vlastností překližovaných desek v závislosti na výrobních parametrech bylo provedeno na souboru překližovaných desek celobukových o nominální tloušťce dýh 1,5 mm. Překližované desky byly vyrobeny jako sedmivrstvé a k jejich výrobě byla použita močovinoformaldehydová pryskyřice DUKOL S. Desky byly lisovány tlakem 1,5 a 1,7 MPa. Byly posuzovány vlastnosti: vlhkost, hustota, pevnost v ohybu, modul pružnosti v ohybu a smyková pevnost (pevnost lepení).

Klíčová slova: překližka; pevnost v ohybu; modul pružnosti v ohybu; pevnost ve smyku; vlhkost; dýha; statistická analýza

Překližované desky jsou definovány jako desky se slepenými vrstvami, přičemž směr vláken sousedních vrstev je obvykle na sebe kolmý. Vnější a vnitřní vrstvy jsou vzhledem ke střední vrstvě na obou stranách symetricky uspořádány. Překližované materiály se vyrábějí lisováním takto vytvořených souborů dýh nanesených syntetickou pryskyřicí v horkých lisech za spolupůsobení tlaku.

Tloušťka překližky je rozměr určující pevnost materiálu. Délku a šířku překližky lze v průběhu řešení konstrukce libovolně měnit (řezáním, nastavováním, speciálními spoji). Tloušťka má na konstrukci značný pevnostní vliv. Například při řešení pevnostních vlastností staveb nebo konstrukcí se řeší nejdříve tloušťka desek a až potom nářezové plány nebo umístění a tvar desek.

Ovlivnění tloušťky tedy znamená ovlivnění fyzikálních a mechanických vlastností desky a tak i stavební nebo jiné konstrukce.

Práce shrnuje výsledky institucionálního výzkumu v oblasti hodnocení a posuzování kompozitních materiálů na bázi dřeva. Cílem práce bylo provedení analýzy rozměrového zmenšení dýh při jejich výrobě a následně po lisování do hotových překližovaných desek. Byly hodnoceny změny vlastností dýh a překližek – tloušťkové rozdíly, sesychání, vlhkost a hustota v závislosti na změnách parametrů při výrobě. Na vylisovaných překližovaných deskách byla zkoumána pevnost v ohybu, MOE a pevnost lepení smykovou zkouškou.

V práci byly posuzovány rozdílné soubory překližovaných desek specifické konstrukce a tedy i odlišných fyzikálních a mechanických vlastností. Tloušťka účelově vyrobených dýh byla měřena ve stanovených místech a dýhy byly vytříděny podle tloušťky od nejnižší po nejvyšší. Byly vytvořeny soubory dýh tak, že první překližka sestávala z nejtenčích a poslední z nejsilnějších dýh. Vznikla tak tloušťková variabilita souboru, která byla následně analyzována.

V důsledku použitého většího lisovacího tlaku 1,7 MPa došlo ke zvýšení koeficientu slisovatelnosti, který se pohyboval od 7,15 do 11,21 % (viz 1. část článku, Journal of Forest Science, *51*, č. 9: 403–411). Tloušťka jednotlivých dýh se zmenšila o 0,112 až 0,186 mm.

Hustota překližovaných desek se zvětšovala s rostoucím lisovacím tlakem. Hodnoty hustoty se pohybovaly od 725,4 do 784,0 kg/m^3 (tab. 1). Pevnost v ohybu byla sledována na dvou typech zkušebních těles – podélných a příčných. Podle platné ČSN EN 310 je stanovena pro příčná tělesa minimální hodnota pevnosti v ohybu ve výši 5 N/mm^2 a pro podélná tělesa 40 N/mm^2. U analyzovaných zkušebních těles byly tyto minimální hodnoty překročeny. U příčných vzorků bylo dosaženo průměrné pevnosti v ohybu od 49,8 do 61,2 N/mm^2 a u podélných od 85,32 do 109,83 N/mm^2.

Největší průměrná hodnota MOE byla stanovena u překližované desky č. 1, a to ve výši 9 695,86 N/mm^2. Nejmenší hodnota MOE byla zjištěna u desky č. 2 – 8 139,34 N/mm^2.

U příčných zkušebních vzorků vykázala největší hodnotu MOE překližovaná deska č. 6 – 4 870,09 N na mm^2 a nejmenší deska č. 2 – 3 970,18 N/mm^2.

Pevnost v ohybu podélných zkušebních vzorků lisovaných tlakem 1,5 MPa vykazovala s rostoucí tloušťkou překližky rostoucí trend. Pro podélné vzorky lisované tlakem 1,7 MPa byl zjištěn klesající trend pevnosti s rostoucí tloušťkou překližované desky. Příčné typy zkušebních vzorků lisované tlakem 1,5 MPa se chovaly stejně jako desky lisované zvýšeným tlakem 1,7 MPa – vykazovaly mírně rostoucí trend pevnosti v ohybu. Byly dosaženy vyšší průměrné hodnoty pevnosti v ohybu překližovaných desek lisovaných tlakem 1,7 MPa oproti deskám lisovaným tlakem 1,5 MPa.

Zjištěná průměrná pevnost ve smyku (pevnost lepení) byla v drtivé většině ve druhé, čtvrté a šesté vrstvě vyšší než 3 N/mm^2, tedy u všech vzorků bylo dosaženo splnění požadavků na hodnotu minimální smykové pevnosti. U vzorků lisovaných zvýšeným lisovacím tlakem 1,7 MPa bylo dosaženo vyšší pevnosti ve smyku. Všechny analyzované překližované desky splnily požadované hodnoty pevnosti v ohybu, MOE a smykové pevnosti.

Posouzení vlastností analyzovaných souborů překližovaných desek potvrdilo, že se zmenšováním tloušťky dýh v překližované desce dochází ke zvýšení koeficientu slisovatelnosti.

MOE a pevnost v ohybu překližovaných desek jsou rozhodujícím způsobem ovlivňovány podíly podélných a příčných dýh v konstrukci desky. Kombinací těchto dýh lze vytvořit překližku požadovaných parametrů. Tento fakt má rozhodující význam pro ekonomicky optimální využití dřevní suroviny při konstrukci překližovaných desek.

Překližované desky lisované z dýh se zápornou tloušťkovou tolerancí mohou přinést vyšší ekonomický efekt znásobený aplikováním nižšího lisovacího tlaku. V důsledku použití vyššího lisovacího tlaku 1,7 MPa se sice dosáhne vyšší pevnosti v ohybu a ve smyku, ale normou požadovaných hodnot bylo docíleno i při použití nižšího lisovacího tlaku 1,5 MPa.

Ekonomického přínosu lze docílit výrobou překližovaných desek z nejtenčích dýh. Tloušťka nejtenčí desky činila 10,16 mm (č. 1) a tloušťka desky s největší průměrnou tloušťkou byla 10,39 mm (č. 7). Tato deska byla lisována nižším tlakem 1,5 MPa. Deska č. 1 byla vyrobena z dýh průměrné tloušťky 1,56 mm. U desky č. 7 činila průměrná tloušťka dýhy 1,62 mm. Rozdíl v tloušťce mezi deskami č. 1 a č. 7 činil 0,06 mm. Znamená to, že mezi nimi bylo dosaženo 3,75 % úspory materiálu.

Na výsledky práce bude navazovat další výzkum, jehož náplní bude posouzení použitelnosti jiných kompozitních materiálů na bázi dřeva ve vztahu k fyzikálním a mechanickým vlastnostem. Cílem bude vytvoření nové konstrukce vrstveného kompozitního materiálu s vyššími užitnými vlastnostmi při minimalizaci výrobních a materiálových nákladů.

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