Property Improvement of Thin High-Density Fiberboard Panels Used as Door-Skins

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Several potential approaches were evaluated to improve the physical and mechanical properties of 3 mm HDF panels used as door-skins. Six different composition recipes were applied by varying the ratio of hardwood-to-softwood fibers and the addition of bark. The density, surface absorption, bending strength, modulus of elasticity, and internal bond of the HDF panels manufactured on an industrial line were determined. The best performance was obtained for the recipe with 20% hardwood fibers, 80% softwood fibers, and less than 5% bark. The influence of spraying the fiber mattress before pressing, by means of water and two different release agents, was also tested. The obtained results are applicable at any HDF producer and can be used for process optimization.

Keywords: High-density fibreboards; Density; Surface absorption; Bending strength; Modulus of elasticity; Internal bond; Composition recipe; Release agent; Process optimization

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INTRODUCTION

High-density fiberboard (HDF) is an engineered wood product made of fine lignocellulosic fibers and a synthetic resin, which are joined together under high pressure and heat to form panels (Irle and Barbu 2010). HDF is a non-load-bearing product for interior use in dry conditions, as its mechanical strengths are modest and it is not moisture-resistant. It is produced in a wide range of thicknesses (from 2 mm to 25 mm). The thinner panels, such as the ones manufactured by KASTAMONU, are mainly used as door-skins (Fig. 1). The main advantages of this material are its high stability, dense and smooth surfaces, and its "woody" aspect. HDF is suitable for different coatings (veneering, laminating, painting, varnishing), and it is very useful for interior design applications due to its easy processing and versatile shapes and colors.

The most important properties of HDF panels used as door-skins are their density, surface absorption, bending strength, modulus of elasticity, and internal bond. The density of HDF significantly influences the dimensional stability of fiberboards (Ayrilmis 2007), and also their mechanical properties (Wong *et al.* 2000), so the general trend is to attain a density as high as possible. According to EN 622-5 (2009), the minimum value is 800 kg/m^3, but optimum values are 1000 kg/m^3 or higher, as long as they do not increase unnecessarily the cost of the product. Optimization is possible by varying the composition of panels (percentage of softwood fibers, hardwood fibers, and bark), considering that fibers from resinous wood are longer and have higher slenderness degree than those from hardwood species (Niemz and Wagenführ 2008), and that wood bark fibers are denser (Miles and Smith 2009) and have different chemical composition than wood fibers

especially in terms of lignin and amount of extractive substances (Harkin and Rowe 1971).

The closing time of the press can also influence the density profile of the board (Wang *et al.* 2001).

Fig. 1. Use of high-density fiberboard as door-skin (produced by Kastamonu Romania)

Surface absorption is the second most important physical property of HDF panels. It has a significant influence on the gluing and varnishing quality and the production costs. Thus, a high surface absorption increases quality, but also the consumption and thus the costs of the finishes, while a too low surface absorption affects the gluing quality. The ideal (envisaged) situation is a clearly differentiated surface absorption on the face and on the back of the panel. The surface absorption on the back should be higher in order to achieve a good gluing on the doorframe, while the surface absorption on the face should be lower to reduce the varnish consumption and thus the product costs. Optimization is possible by using different filling mixtures (Danuta and Monder 2015), but also by using release agents to wet the fiber mattress before it enters the press, or by varying some pressing parameters (*e.g.*, the closing time).

The bending strength represents the most important mechanical property of any wood-based panel, as it characterizes its consistency and the ability to withstand external factors of stress and destabilization. Alpar *et al.* (2010) made an interesting comparison between the bending strength of MDF and HDF panels made from different fast-growing species.

The modulus of elasticity in bending characterizes the ability of the HDF door-skin to adhere to the shape of the doorframe, even if this contains 3D-mouldings, and therefore it is of utmost importance. According to EN 622-5 (2009), the minimum value required is 2700 N/mm^2, but according to the authors' expertise, this should be at least 3500 N/mm^2 in order to provide proper stability and strength.

The internal bond represents another important mechanical feature of the HDF

panel, which characterizes the gluing quality and also the property-uniformity of the panel in different directions and planes. It is directly influenced by the panel density and by the accuracy of the glue-spreading process. The closing time of the press is also important in this regard: it has to be as short as possible to enhance the formation of solid crystalline bonds between the fibers.

The standard (minimum) requirements for these properties according to EN 622-5 (2009) are presented in Table 1.

Table 1. Standard Requirements for the Selected Properties of HDF Panels According to EN 622-5 (2009)

Density (kg/m^3)	Surface Absorption (mm)	Bending Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Internal Bond (N/mm^2)
800	150	23	2700	0.65

However, the main aim of this research was to increase the performances of the HDF panels beyond these minimal requirements, and therefore, different compositions in terms of hardwood / softwood fibers ratio and bark content were tested. Additionally, different release agents were used during the fiber mattress formation. The physical and mechanical properties of the thin HDF panels and the overall quality of the product were investigated.

EXPERIMENTAL

Materials, Methods, and Equipment

The 3-mm thick raw high-density fiberboards (HDF) were manufactured on the industrial line at Kastamonu Romania (Reghin, Romania). Six combinations were produced by varying the percentage of hardwood and softwood fibers in three variants (20/80; 30/70; 40/60) and the amount of bark in two variants (below and above 5%). Approximately 7000 pieces of HDF panels were produced from each recipe. The pressing parameters were as follows: temperature (T) of 150 °C, pressing time (t) of 30 s, pressure (p) of 180 bar, and press closing time ($t_{closing}$) of 2 s.

To test the influence of a release agent sprayed over the panel face before pressing, three alternatives were investigated: water, the release agent PAT® 2003 XE (Würtz, Bingen am Rhein, Germany), and the release agent MOULEX WE07BSP (Additek, Moreuil, France), which were both diluted in water to a 4% concentration.

PAT® 2003 XE is a concentrated, water-soluble release agent, while MOULEX WE07BSP is a release agent based on two different surface-active compounds,

- EMPHOS PS 236 (CAS 68908-64-5) - (C10-C12) alkylethoxylate-mono-phosphate;
- Isotridecanol (CAS 27458-92-0)-11-methyldodecan-1-ol

in a mixture of 2-amino-etanol and 2 propanol, with an addition of 1% biocidal products (5-chloro-2-methyl-3(2H)-isothiazolone with 2-methyl-3(2H)-isothiazolone) (CAS 55965-84-9) (www.chemicalbook.com/ChemicalProductProperty).

After pressing, the boards were conditioned for 30 min at ambient temperature, and specific test pieces were cut out of eight randomly selected panels from each recipe, according to EN 326-1 (1994). The most relevant physical and mechanical properties of HDF boards used as doorskins were determined, including the density, surface absorption, bending strength, modulus of elasticity in bending, and internal bond.

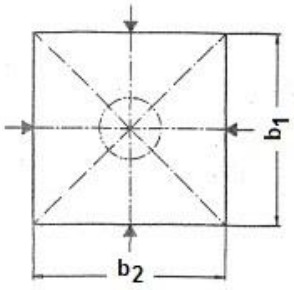


Fig. 2. Measuring the dimensions of the test pieces for HDF density determination

Density

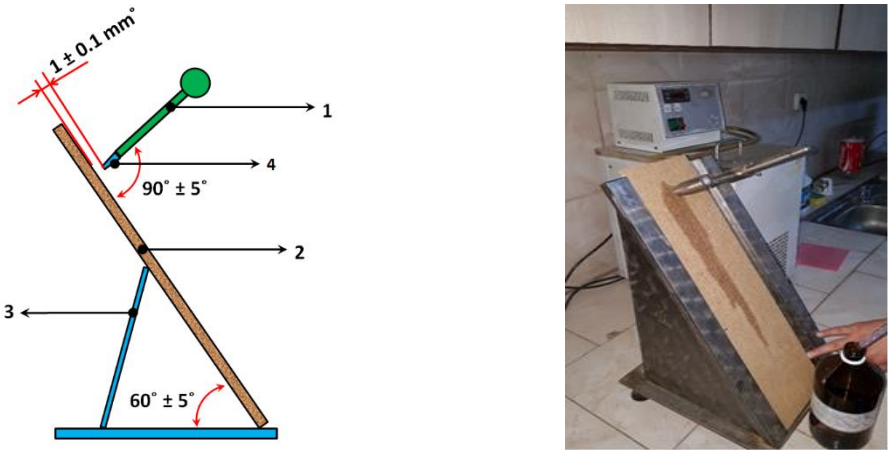
The HDF density was determined according to EN 323 (1996). Sixteen test pieces from each of the eight test-panels from each recipe, sized at 100 mm x 100 mm x 3 mm, were first weighed at an accuracy of 0.01 g. The thickness (*t*) was measured in the central point by a micrometer at an accuracy of 0.01 mm, and the dimensions b_1 and b_2 were measured at mid width and length, according to Fig. 2, by a sliding gauge at an accuracy of 0.1 mm. The density of each test piece was then calculated as follows,

$$\rho = \frac{m}{b_1 \cdot b_2 \cdot t} \cdot 10^6 [kg/m^3] \quad (1)$$

where *m* is the sample mass (g), b_1, b_2 are the sample dimensions (mm), and *t* is the sample thickness (mm).

Surface Absorption

The surface absorption was determined according to EN 382-1 (1993). Three test pieces from each of the eight test-panels from each recipe, sized at 100 ± 2 mm × 500 ± 2 mm × 3 mm, were placed on a (60 ± 5)° inclined support (Fig. 3).



a. **b.**

Fig. 3. Determination of the surface absorption of HDF panels: a-principle, with 1-pipette; 2-test piece; 3-inclined support; b-experimental set-up

The pipette for dropping the toluene solution was placed at a distance of 1 ± 0.1 mm, perpendicular to the panel surface. A total of 1 mL of toluene was dropped twice on the panel surface at a time interval of 4 s and left to flow. The maximum length of the trace was measured along a line parallel to the test piece margins, at an accuracy of ± 1 mm. The operation was repeated on the other panel face. The values obtained, represented the surface absorption (*As*), in mm, with differentiated values on the panel face and on the panel back, respectively.

Bending Strength and Modulus of Elasticity in Bending

The bending strength and modulus of elasticity in bending were determined according to EN 310 (1993) (Fig. 4a). Six samples from each of the eight test-panels from each recipe, sized at 150 mm × 50 mm × 3 mm, were tested by on Z010 equipment, manufactured by ZWICK GmbH & Co. (Ulm, Germany) (Fig. 4b).

The distance between the centers of the supports was adjusted at 100 mm. The test piece was placed flat on the supports, with its longitudinal axis at right angles to those of the supports with the center point under the load, as shown in Fig. 4a. The load was applied at a constant rate of the cross-head movement throughout the test. The rate of loading was adjusted so that the maximum load was reached within 60 ± 30 s. The deflection in the middle of the test piece (below the loading head) was measured to an accuracy of 0.1 mm. These values were plotted against the corresponding loads measured to an accuracy of 1% of the measured value. The maximum load was recorded to an accuracy of 1% of the measured value.

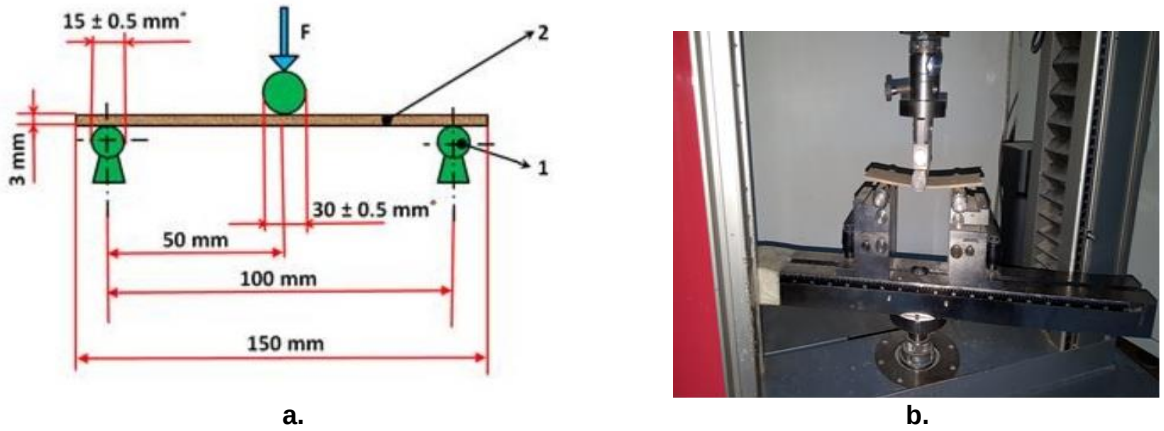


Fig. 4. Determination of the bending strength and modulus elasticity in bending of HDF panels: a-principle, with 1-supports; 2-test piece; F-loading force; b-ZWICK 010 testing machine

The bending strength of each test piece (f_m) was calculated according to Eq. 2,

$$f_m = \frac{3 \cdot F_{max} \cdot l_1}{2 \cdot b \cdot t^2} [N/mm^2] \quad (2)$$

where F_{max} is the maximum load (N), l_1 is the distance between the centers of the supports (mm), b is the test piece width (mm), and t is the test piece thickness (mm).

The modulus of elasticity in bending (E_m) was calculated according to Eq. 3,

$$E_m = \frac{l_1^2 \cdot (F_2 - F_1)}{4 \cdot b \cdot t^2 \cdot (a_2 - a_1)} [N/mm^2] \quad (3)$$

where ($F_2 - F_1$) is the increment of load on the straight line portion of the load-deflection curve, and ($a_2 - a_1$) is the deflection increment at the mid length of the test piece corresponding to ($F_2 - F_1$).

Internal Bond

The internal bond was determined according to EN 319 (1993) (Fig. 5a). Four samples from each of the eight test-panels from each recipe, sized at 50 mm × 50 mm × 3 mm, were used. Each sample was first glued to the metallic jig with a melting adhesive (Fig. 5b) and then subjected to a tensile force (Fig. 5c) on the same ZWICK Z010 equipment until rupture occurred. The maximum force that produced failure was recorded, and the internal bond was calculated according to Eq. 4,

$$f_{t1} = \frac{F_{max}}{a \cdot b} [N / mm^2] \quad (4)$$

where F_{max} is the maximum load (N) and a, b are length and width of the test piece (mm).

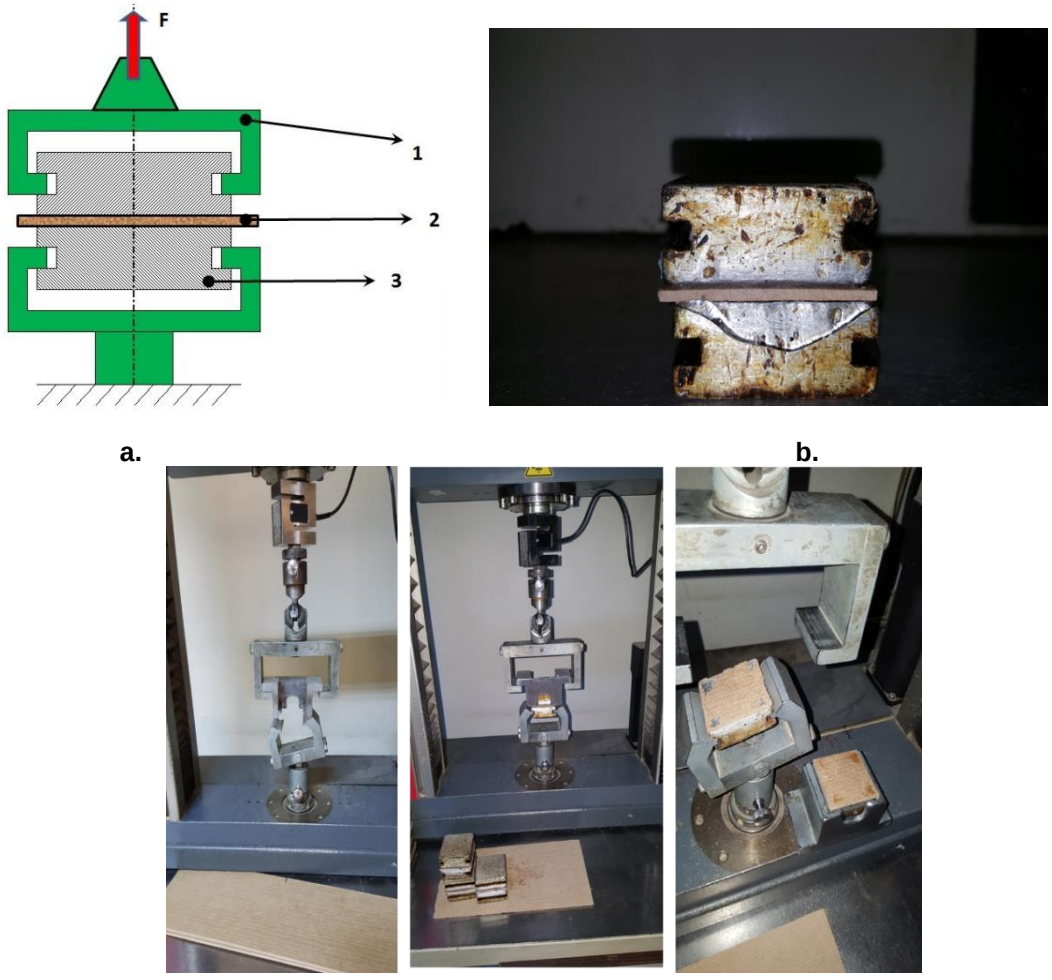


Fig. 5. Determination of the internal bond of HDF panels: a – principle, with: 1 – clamping device; 2 - test piece; 3 – metallic jig; F-load (tensile force); b – gluing of wooden sample on metallic jig; c - ZWICK Z010 testing machine

Statistical Analysis

One-way between-groups analysis of variance (ANOVA) was conducted to explore the influence of the hardwood/softwood fibers ratio and bark content on all selected properties of 3 mm thick HDF panels.

RESULTS AND DISCUSSION

Influence of the Composition Recipe on the Physical and Mechanical Properties of HDF Panels

The influence of the hardwood/softwood fibers ratio and bark content in the composition of HDF panels upon their properties is presented in Table 2 and Fig. 6. As one may notice, all mean values of the selected properties exceeded the standard requirements (Table 1). There was a statistically significant difference among the analyzed combinations of raw materials in terms of all selected physical and mechanical properties. The descriptive statistics, ANOVA results, post-hoc comparisons using the Tukey HSD, and effect size are also presented in Table 2.

Table 2. Influence of the Hardwood/Softwood Fibers Ratio and Bark on the Properties of 3 mm thick HDF Panels

Combination	Raw Materials		Density (kg/m^3)	Surface Absorption (mm)		Bending Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Internal Bond (N/mm^2)
	Hardwood/ Softwood Fibers (%)	Bark (%)		Face	Back			
1	20/80	≤5	1078^{ac} (26.55)	446^{abc} (38.62)	398^{abc} (34.68)	79.6^{ac} (3.28)	6806 (196.84)	2.5 (0.17)
2	20/80	>5	1050^{bce} (21.70)	420^{abc} (37.75)	355^{abcf} (30.36)	71.2^{bcef} (2.20)	5583^{a} (82.87)	1.7^{abcd} (0.23)
3	30/70	≤5	1063^{abc} (20.39)	405^{abce} (18.02)	410^{abc} (18.02)	77.74^{abc} (3.39)	6223 (377.95)	2.04^{abc} (0.16)
4	30/70	>5	955^{df} (23.19)	217^{d} (31)	263^{def} (6.81)	62.57^{def} (4.01)	5513^{a} (377.99)	1.78^{abcd} (0.29)
5	40/60	≤5	1025^{be} (28.63)	337^{cef} (17.06)	227^{de} (7.55)	68.96^{bdef} (4.66)	4896^{b} (355.85)	2.08^{abc} (0.08)
6	40/60	>5	935^{df} (29.40)	229^{df} (14.11)	305^{bdf} (10.00)	64.86^{bdef} (4.88)	4926^{b} (170.96)	1.60^{ad} (0.08)
F-value			88.91	37.71	36.97	18.85	41.09	12.27
Significance level			$p < 0.05$					
Effect size (Eta squared)			0.88	0.94	0.93	0.67	0.87	0.77

Note: Mean values are shown, with standard deviations in parentheses; Means followed by the same letter are not significantly different.

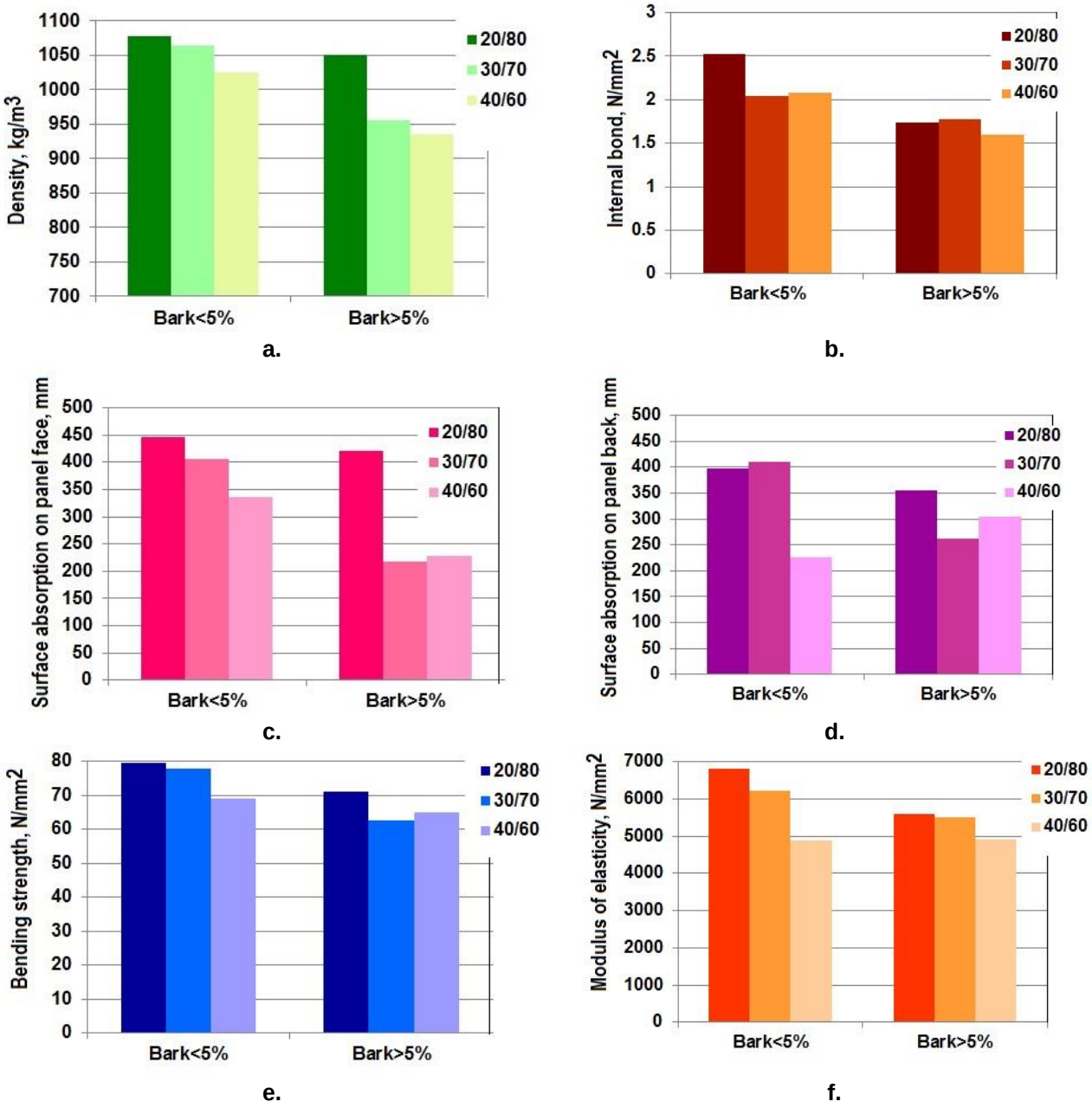


Fig. 6. Physical and mechanical properties of HDF panels: a-density; b-internal bond; c-surface absorption on the panel face; d-surface absorption on the panel back; e-bending strength; f-modulus of elasticity in bending

As far as the **influence of the different species ratio** is concerned, it was established that reducing the percentage of softwood fibers from 80% to 60% in favor of the hardwood (beech) fibers, gave rise to the following results:

- The density decreased by 4.9% and 10.9% for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction in both cases;
- The surface absorption on the face decreased by 24.4% and 45.4% for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction in the latter case;

- The surface absorption on the back decreased by 43.0% and 14.1% of for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction only for the low bark amount;
- The bending strength decreased by 12.1% and 8.9% for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction only for the low bark amount;
- The modulus of elasticity in bending decreased by 28.1% and 11.7% for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction in both cases;
- The internal bond decreased by 16.8% and 5.9% for the bark content ≤ 5% and > 5%, respectively, which was a significant reduction only for the low bark amount.

These results show that increasing the ratio of beech fibers in the recipe did not benefit the panel density and the related mechanical properties. The best results were obtained for the recipes with the minimum percentage (20%) of hardwood fibers, both in the case with lower bark amount (≤ 5%) and higher bark amount (> 5%).

Based on the resulting eta squared (Table 2) and Cohen's classification, with 0.01 as a small effect, 0.06 as a medium effect and 0.14 as a large effect (Pallant 2007), it could be established that the raw materials composition has a large effect on the properties of 3 mm thick HDF panels.

As far as the **influence of the bark amount** is concerned, all recorded values were lower for the panels with more bark: they were less dense, less absorptive, weaker, less elastic, and had poorer gluing. The trends are illustrated by the graphs in Fig. 7.

Thus, the recipe resulting in the best mechanical performance (highest bending strength, modulus of elasticity, and internal bond) included 20% hardwood fibers, 80% softwood fibers, and ≤ 5% bark. Although the values of the surface absorption were the highest with this recipe, it was one of the few recipes for which the surface absorption on the back was lower than on the face (by 10.7%), which is an essential advantage.

Influence of the Release Agent on the Physical and Mechanical Properties of HDF Panels

Spraying the panel surface before pressing is a common procedure to avoid the sticking of the HDF sheet on the press platen. The authors found it interesting to investigate how and to what extent the release agent influences the physical and mechanical properties of the panel. An improvement of the surface absorption was especially envisaged.

The panel made with 20% hardwood fibers, 80% softwood fibers, and < 5% bark was tested with three spraying materials: water, the release agent type PAT 2003 XE (Würtz), and the release agent type MOULEX WE07BSP (Additek). The results are presented in Table 3 and Fig. 8.

One-way between-groups analysis of variance (ANOVA) was conducted to explore the influence of the release agent on the physical and mechanical properties. There was a statistically significant difference among analyzed combinations of raw materials in terms of all selected properties. The descriptive statistics, ANOVA results, post-hoc comparisons using the Tukey HSD, and effect size are also presented in Table 3.

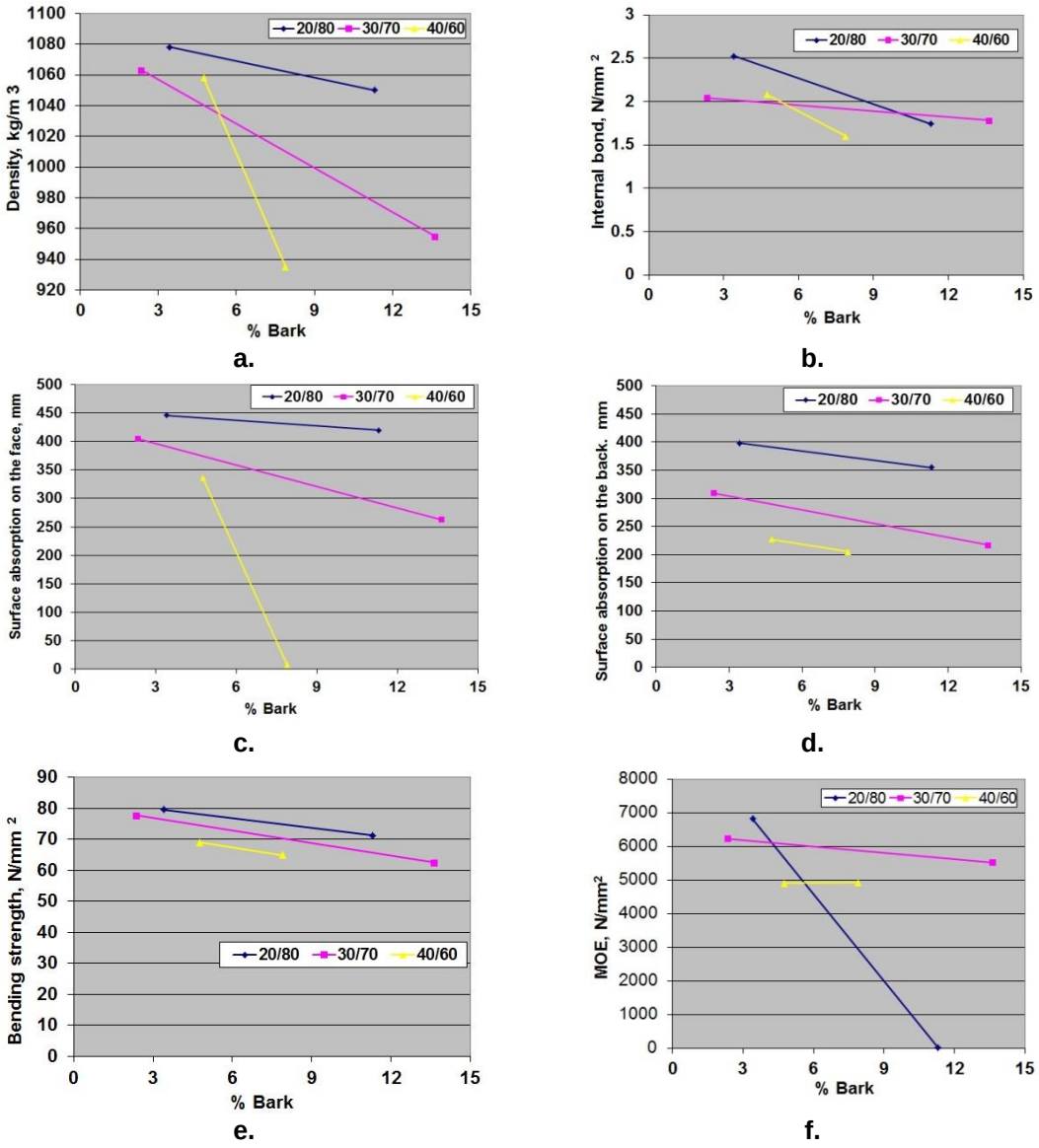


Fig. 7. Influence of the bark amount upon the physical and mechanical properties of HDF panels: a-density; b- f-internal bond; c-surface absorption on the panel face; d-surface absorption on the panel back; e-bending strength; f-modulus of elasticity in bending

All mechanical properties were lowered by the use of the spraying agent. The lowest (worst) values were obtained when spraying with water, which resulted in significant reduction by 24.1% of the bending strength, by 34% of the elasticity modulus, and by 40.5% reduction of internal bond. However, even these values are higher than standard requirements. The best results were obtained with the release agent PAT 2003 XE, which produced only 6.9% reduction of bending strength, 8.4% reduction of elasticity modulus, and 27% reduction of internal bond.

Table 3. Influence of the Release Agent on the Properties of 3-mm HDF Panels

Release Agent	Density (kg/m^3)	Surface Absorption (mm)		Bending Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Internal Bond (N/mm^2)
		Face	Back			
None	1078^{ab} (26.55)	446^{ab} (38.62)	398^{a} (34.68)	79.60^{ab} (3.28)	6806 (196.84)	2.52 (0.18)
Water	1076^{ab} (22.39)	443^{ab} (21.93)	380^{a} (14.00)	60.36 (5.30)	4493 (356.24)	1.5^{a} (0.30)
PAT 2003 XE	1026^{c} (38.25)	397^{ab} (41.68)	350^{a} (31.43)	74.09^{ab} (5.14)	6233 (446.35)	1.84^{a} (0.16)
MOULEX WE07BSP	1005^{c} (25.37)	333^{b} (15.70)	246 (10.07)	71.36^{b} (3.24)	5380 (369.76)	1.40^{a} (0.39)
F-value	25.59	8.41	22.35	20.74	48.87	13.99
Significance level	$p < 0.05$					
Effect size (Eta squared)	0.56	0.75	0.89	0.75	0.87	0.77

Note: Mean values are shown, with standard deviations in parentheses. The panel was made of 20% hardwood fibers, 80% softwood fibers, and > 5% bark. Means followed by the same letter are not significantly different.

The density remained close to the one of the control pieces (with no spraying) only in the case of spraying with water. With the two release agents, it decreased significantly, by 4.8% and 6.7%, respectively.

Regarding surface absorption (Fig. 8), no significant differences were recorded.

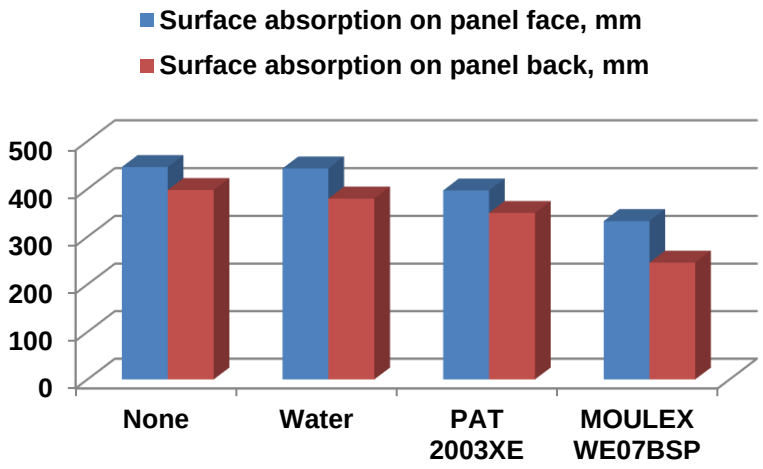


Fig. 8. Influence of the release agent upon the surface absorption of HDF panels

With the MOULEX WE07BSP release agent, a reduction by 25.3% on the panel face and by 38.19% on the panel back was obtained, compared to the control pieces (with no spraying). However, after a certain time of use, the release agent began to foam, which was a disadvantage, because an anti-foaming additive had to be added.

The second best results concerning the reduction of the surface absorption were obtained with the Würtz PAT 2003 XE release agent: reduction by 11% on the panel face and by 12% on the panel back. The absence of foaming is a strong point in favor of this

release agent.

The values presented in Table 3 enable each producer to choose according to their own priorities.

The resulting eta squared (Table 3) indicated that the release agent also had a large effect on the physical and mechanical properties of 3 mm thick HDF panels.

CONCLUSIONS

1. By varying the raw material recipe from 20% hardwood fibers + 80% softwood fibers to 40% hardwood fibers + 60% softwood fibers, all physical and mechanical properties of 3 mm thick HDF were lowered.
2. The bark content in the composition recipe is also very important: with bark contents >5%, all HDF properties decrease, especially the mechanical ones.
3. The composition recipe, which was considered optimum, especially considering the mechanical performances, was the one with 20% hardwood fibers, 80% softwood fibers, and ≤ 5% bark, although it registered the highest values of the surface absorption.
4. The improvement (reduction) of the surface absorption is possible by using release agents, although this measure leads to some mechanical weakening. The best results (lowest values both on the face and on the back of the panel + surface absorption on the panel back distinctive lower than on the panel face) were obtained with the MOULEX WE07BSP release agent. The PAT 2003 XE release agent by Würtz was remarked due to the absence of foaming tendency and better mechanical performances, close to the ones obtained with no spraying.
5. The obtained results are applicable at any HDF producer, and can be used for process optimization.

REFERENCES CITED

Alpar, T., Faczan, T., Racz, I., and Katoli, G. (2010). "MDF/HDF production from plantation wood species," *Drvna Industrija* 61(3), 183-191.

Ayrilmis, N. (2007). "Effect of panel density on dimensional stability of medium and high density fibreboards," *Journal of Materials Science* 42(20), 8551-8557. DOI: 10.1007/s10853-007-1782-8.

Danuta, N., and Monder, S. (2015). "Influence of filling mixtures on the properties of HDF surface," *Annals of Warsaw University of Life Sciences – SGGW Forestry and Wood Technology* 89, 112-115.

EN 310 (1993). "Wood-based panels: Determination of modulus of elasticity in bending and of bending strength," European Committee for Standardization, Brussels, Belgium.

EN 319 (1993). "Particleboards and fibreboards. Determination of tensile strength perpendicular to the plane of the board," European Committee for Standardization, Brussels, Belgium.

EN 323 (1993). "Wood-based panels. Determination of density," European Committee

for Standardization, Brussels, Belgium.
EN 326-1 (1994). "Wood-based panels: Sampling and cutting of test pieces and inspection," European Committee for Standardization, Brussels, Belgium.
EN 622-5 (2009). "Fibreboards. Specifications. Requirements for dry process boards," European Committee for Standardization, Brussels, Belgium.
Harkin, J. M., and Rowe, J. W. (1971). *Bark and Its Possible Uses.* Research Note. USDA Forest Service.
Irle, M., and Barbu, M. C. (2010). "Wood-based panel technology," in: *Wood-based Panels – An Introduction for Specialists*, H. Thoemen, M. Irle, and M. Sernek (eds.) Brunel University Press, London, pp. 1-94.
Miles, P. D., and Smith, W. B. (2009). *Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America.* US Forest Service.
Niemz, P., and Wagenführ, A. (2008). "Werkstoffe aus Holz," in *Taschenbuch der Holz-technik,* Facbuchverlag Leipzig im Carl Hanser Verlag. ISBN 978-3-446-22852-8.
Pallant, J. (2007). *SPSS. Survival manual. A Stept-by-Step Guide To Data Analysis using SPSS version 15. Third Edition*. McGraw Hill, Open University Press.
Wang, S., Winistorfer, P. M., Young, T. M., and Helton, C. (2001). "Step-closing pressing of medium-density fiberboard. Part 1. Influences on the vertical density profile," *Holz als Roh- und Werkstoff* 59(2001), 19-26. DOI: 10.1007/s001070050466.
Wong, E. D., Zhang, M., Han, Q. W. G., and Kawai, S. (2000). "Formation of the density profile and its effects on the properties of fibreboard," *Journal of Wood Science* 46(3), 202-209. DOI: 10.1007/BF00776450.
www.chemicalbook.com/ChemicalProductProperty

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