The Utilization of Chips from Comminuted Wood Waste as a Substitute for Flakes in the Oriented Strand Board Core

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Abstract

This study evaluated the applicability of substituting flakes in the core layer of oriented strand board (OSB) with chips from comminuted and unrefined particle boards and wood waste. Results from the analyses show that the applied modification of the core, even at a relatively high proportion of chips (amounting to 75%) makes it possible to manufacture OSB with good mechanical properties, meeting the requirements of the standard EN 300. In contrast, the use of melamine–urea–phenol–formaldehyde resin does not guarantee the requirements (in terms of moisture resistance) will be met.

Scientific and technological data concerning oriented strand board (OSB) production have been collected for over 50 years now. The intention in introducing such a wood-based material was to develop a large-size composite panel with considerable mechanical strength and high resistance to fluctuating environmental conditions, while simultaneously maintaining relatively low production costs. OSB, with intended applications similar to those of plywood, proves quite competitive to plywood in certain situations, owing to successive layers being oriented at a 90° angle to one another. Typically three-layer OSB is manufactured so that face layers are oriented along the production line (//, the longer axis), while the core is oriented perpendicular to them (⊥, the shorter axis). It is also possible to produce five-layer boards. The necessary precondition for the manufacture of an oriented board with high mechanical properties is to use chips with an appropriate slenderness ratio (the ratio of length to thickness of chips), typically amounting to 150 (Brinkmann 1979). The other condition is to obtain a maximum degree of chip orientation or the orientation index (the $\mathrm{MOR}_{//}/\mathrm{MOR}_{\perp}$ ratio, which for commercial boards amounts to 1.7:3; Bücking 1977). Both conditions are met by chips of 75 to 120 mm in length, 20 to 30 mm in width, and 0.3 to 0.7 mm in thickness (Keiser 1987, Chen et al. 2008). It was shown that the use of chips longer than 150 mm does not result in a significant improvement of mechanical properties of such boards (Barnes 2000, 2001), while the application of shorter chips, as might be expected, deteriorates the boards' properties (Nishimura et al. 2004). Investigations conducted by Mirski (2009) on commercial OSB with a thickness of 8 mm displayed over 80 percent higher bending strength and a 65 percent higher modulus of elasticity for the longer axis than required for the binding standard PN-EN 300 (European Committee for Standardization [CEN] 2006). Thus, there is a certain ‘‘surplus’’ of mechanical properties in OSB panels that may be reduced to some degree, and these boards would still meet the requirements of the standard. The application of small-sized chips of various origin, e.g., chips produced on site when cutting flakes or chips produced elsewhere, would significantly reduce OSB production costs. In the early 1980s it was observed that the amount of small-sized chips produced when cutting flakes is considerable and may be in excess of 20 percent by weight of the total flakes cut. One idea for their use was combustion in the plant boiler room. The other, possibly a more rational idea, was to add them to the core of OSB panels. Studies conducted on this use have shown that substituting normally used flakes in the OSB core with a small amount of chips (up to 30%) does not significantly reduce the mechanical properties of the resultant OSB panels (Brinkmann 1979, Ehrentreich 1980, Barnes 2002, Jastrząb 2008). In turn, Lee and Tahir (2003)

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presented results at the 12th World Forestry Congress of studies in which they proposed using a fraction of fines below 0.1 mm in the face layers, thus forming a five-layer OSB with a very smooth surface. The presented solution has the obvious advantage that such a panel may be additionally refined. In turn, Fakhri and co-workers (2006a, 2006b) investigated the effect of fines on transverse permeability of OSB and presented a general mathematical model describing this phenomenon and stated that fines may be successfully used for every type of boards manufactured from particles of different chip sizes. From our literature search on the subject, the utilization of small-sized chips in the production of OSB is not a novel solution. However, it is of interest in view of not only legal but also social aspects of recycling as proposed by Hermawan et al. (2007), who suggested manufacturing OSB by using chips of conventional sizes derived from postconsumer wood.

In view of the limited literature published to date on the potential applications in OSB manufactured with small chips and conventional flakes cut from postconsumer material, we decided to investigate whether and to what degree it is possible to substitute chips in the OSB core with small chips from comminuted wood wastes and unrefined particle boards.

Materials and Methods

Commercial pine flakes were used in the manufacture of experimental OSB. Small-sized chips to be used in the core were produced by grinding solid wood fragments (carpentry waste, denoted as Scrap) and unrefined particle board type P2 (furniture board, denoted as Eco) in a laboratory mill. The pretreated batch of small-sized chips was sieved at a mesh size of 1 by 1 mm in order to separate dust and fine fractions. The composition of small-sized chips in each fraction is presented in Table 1. In both cases, chips remaining on sieve mesh sizes of 2.5 and 1 mm predominated. It was assumed that the proportion of small-sized chips would range from 0 to 100 percent, with a 25 percent increment in the total share of chips in the core.

For each variant, three three-layer OSB panels were prepared using such chips, with the assumed board density of 600 kg/m^3 and thickness of 15 mm. Melamine–urea–phenol–formaldehyde (MUPF) resin was used to resinate the boards. The adopted proportion in weight of individual layers was 1:2:1 (face/core/face). A uniform layer resination rate of 5 percent was used when the core was composed of flakes, and the resination rate was increased by 0.25 percent for each 25 percent addition of small-sized chips. Under hot pressing conditions, the hot plate temperature was adjusted to 210°C, and the hot press time was adjusted to 255 seconds (Table 2).

Table 1.—The fraction composition of small-sized chips.

Fines screen size (mm by mm)	Chips (%)	
	Scrap	Eco
>6.3	2.2	1.3
>5	6.2	2.9
>4	5.5	1.6
>2.5	35.1	38.8
>1	48.0	51.5
>0.5	2.5	3.0
<0.5	0.6	0.8

Table 2.—Characteristics of the pressing process of oriented strand board.

Proportion of small-sized chips (%)	Resin content (%)		Time factor (mm/s)	Temp (°C)	Pressure (bar)
	Face	Core			
0	5.0	5.00	17	210	25
25		5.25			
50		5.60			
75		5.75			
100		6.00			

Thus, manufactured OSB variants were tested, in accordance with the respective standards, in terms of such properties as

- modulus of rupture (MOR) and modulus of elasticity (MOE) according to EN 310 (CEN 1993a);
- internal bond (IB) according to EN 319 (CEN 1993c);
- swelling in thickness (TS) after 24 hours according to EN 317 (CEN 1993b);
- water resistance determined by the V-100 test according to EN 1087-1 (CEN 1999b); and
- formaldehyde content determined by the perforator test according to EN 120 (CEN 1994).

Although in Poland OSB is generally produced either by resination with polymeric diphenylmethane diisocyanate (pMDI) only or in the system of the core being resinated with pMDI and face layers with MUPF resin, boards were resinated with MUPF only in this study. This type of resin is commonly used in the manufacture of wood-based composites with enhanced water resistance. However, wood-based materials manufactured using only this type of resin exhibit lower water resistance than those to which pMDI has been applied. For this reason, this adhesive is used only in the pMDI/MUPF system in the manufacture of OSB/3 and OSB/4,[1] which face strict requirements in terms of water resistance due to their range of applications. Also, OSB manufactured within our study, even with the use of a paraffin emulsion introduced together with the adhesive mixture at 2 percent of the dry mass of the wood, confirmed a slight water resistance of boards resinated with MUPF only (Table 3). As the results show, the addition of paraffin only improves their thickness swelling properties.

Such a low water resistance of manufactured boards is probably the result for the low resination rate (maximum, 6%). Obviously, its increase would considerably improve board properties in this respect. However, the aim of this study was not to show that this type of resin makes the manufacture of completely water-resistant OSB possible, but rather to demonstrate a possible substitution of flakes in the OSB core with small-sized chips. Thus, in order to minimize the advantageous effect of the proportion of adhesive on the mechanical properties of the boards, we decided to apply a low chip resination rate. It also needs to be stressed that the control board manufactured with the addition of paraffin emulsion in this study (denoted as board B, Table 3) was used only for comparative purposes in terms of water resistance. Results of testing for mechanical properties of manufactured boards depending on the

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[1] OSB/3 load-bearing boards for use in humid conditions; OSB/4 heavy-duty load-bearing boards for use in humid conditions.

composition of their core were based on the control board (board A).

Results and Discussion

Properties of OSB containing small-sized chips as a substitute for flakes in their core are presented in Tables 3 through 5. As might be expected, the applied modification did not have a significant effect on bending strength or MOE determined in the longer axis. The recorded strength values for individual boards amounted to 35 ± 2 N/mm^2. Thus, the observed changes in the strength did not exceed 6 percent and were random in character, possibly resulting from the quality of flakes found in the immediate site of rupture and not the quality of chips in the core. Still smaller fluctuations were observed for the MOE, for which changes did not exceed 4 percent, with a mean value for all boards of 6,500 N/mm^2. A lack of changes in the MOR and MOE for the longer axis shows that face layers played a decisive role for this direction. The quality of chips and the high degree of

Table 3.—Characteristics of tested oriented strand board.

Property[a]	Testing method	OSB/3[b]	Control board[c]	
			A	B
ρ (kg/m^3)	EN 323[d]	—	610 (14)	630 (24)
MOR$_{//}$ (N/mm^2)	EN 310	20	35.0 (2.1)	32.0 (3.4)
MOE$_{//}$ (N/mm^2)	EN 310	3,500	6,610 (330)	6,900 (540)
MOR$_\perp$ (N/mm^2)	EN 310	10	20.0 (1.3)	18.6 (1.6)
MOE$_\perp$ (N/mm^2)	EN 310	1,400	2,240 (150)	2,780 (170)
IB (N/mm^2)	EN 319	0.32	0.64 (0.04)	0.59 (0.07)
TS (%)	EN 317	<15	33.6 (2.0)	16.8 (2.2)
V-100 (N/mm^2)	EN 1087-1	0.13	—	0.02 (0.005)
Perforator value (mg/100 g oven dry board)	EN 120	≤8	4.87 (—)	4.13 (—)

[a] MOR = modulus of rupture; MOE = modulus of elasticity; // = parallel; ⊥ = perpendicular; IB = internal bond; TS = thickness swelling.

[b] According to EN 300.

[c] A = without paraffin wax addition; B = with paraffin wax addition at 2 percent of the dry mass of the wood. Standard deviations are presented in parentheses.

[d] European Committee for Standardization (1999a).

Table 4.—Characteristics of tested oriented strand board—scrap.

Property[a]	Testing method	Proportion of small-sized chips in the core[b]					ANOVA[c]	
		0%	25%	50%	75%	100%	*F*	*P*
ρ (kg/m^3)	EN 323	610 (14)	620 (26)	620 (16)	620 (15)	595 (17)	5.84	0.000
MOR$_{//}$ (N/mm^2)	EN 310	35.0 (2.1)	35.0 (3)	36.9 (2.2)	34.2 (2.0)	35.2 (1.8)	2.58	0.044
MOE$_{//}$ (N/mm^2)	EN 310	6,610 (330)	6,550 (330)	6,460 (200)	6,420 (240)	6,470 (230)	0.84	0.506
MOR$_\perp$ (N/mm^2)	EN 310	20.0 (1.3)	17.4 (1.9)	15.8 (0.7)	14.8 (1.7)	12.7 (1.2)	64.02	0.000
MOE$_\perp$ (N/mm^2)	EN 310	2,240 (150)	2,180 (160)	2,090 (120)	2,020 (300)	1,970 (60)	5.99	0.000
IB (N/mm^{-2})	EN 319	0.64 (0.04)	0.63 (0.07)	0.62 (0.05)	0.60 (0.02)	0.60 (0.03)	2.37	0.061
TS (%)	EN 317	33.6 (2.0)	29.6 (2.4)	29.1 (2.9)	28.2 (0.8)	26.9 (2.4)	19.98	0.000
V-100 (N/mm^2)	EN 1087-1	—	—	—	—	—	—	—
Perforator value (mg/100 g dry board)	EN 120	4.87 (—)	—	5.55 (—)	—	6.10 (—)	—	—

[a] MOR = modulus of rupture; MOE = modulus of elasticity; // = parallel; ⊥ = perpendicular; IB = internal bond; TS = thickness swelling.

[b] Standard deviations are presented in parentheses.

[c] Confidence level = 0.05.

Table 5.—Characteristics of tested oriented strand board—Eco.

Property[a]	Testing method	Proportion of small-sized chips in the core[b]					ANOVA[c]	
		0%	25%	50%	75%	100%	*F*	*P*
ρ (kg/m^3)	EN 323	610 (14)	615 (28)	615 (26)	595 (25)	620 (22)	2.87	0.029
MOR$_{//}$ (N/mm^2)	EN 310	35.0 (2.1)	34.9 (3.0)	33.0 (1.9)	34.8 (4.1)	33.1 (3.5)	1.659	0.169
MOE$_{//}$ (N/mm^2)	EN 310	6,610 (330)	6,750 (350)	6,500 (460)	6,390 (400)	6,310 (320)	3.250	0.016
MOR$_\perp$ (N/mm^2)	EN 310	20.0 (1.3)	17.4 (2.0)	15.2 (1.4)	12.4 (0.9)	9.9 (1.4)	111.8	0.000
MOE$_{\perp;}$ (N/mm^2)	EN 310	2,240 (150)	2,040 (170)	1,860 (100)	1,670 (110)	1,550 (140)	61.69	0.000
IB (N/mm^2)	EN 319	0.64 (0.04)	0.56 (0.02)	0.47 (0.03)	0.42 (0.03)	0.32 (0.03)	217.58	0.000
TS (%)	EN 317	33.6 (2.0)	32.8 (3.7)	29.6 (1.8)	31.0 (2.1)	29.9 (2.9)	8.65	0.000
V-100 (N/mm^2)	EN 1087-1	—	—	—	—	—	—	—
Perforator value (mg/100 g dry board)	EN 120	4.87 (—)	—	5.78 (—)	—	6.21 (—)	—	—

[a] MOR = modulus of rupture; MOE = modulus of elasticity; // = parallel; ⊥ = perpendicular; IB = internal bond; TS = thickness swelling.

[b] Standard deviations are presented in parentheses.

[c] Confidence level = 0.05.

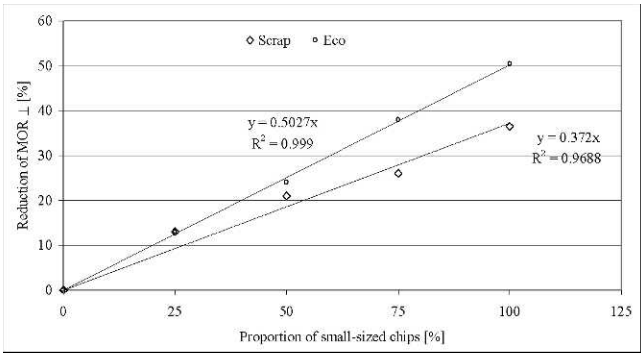

Figure 1.—A reduction in bending strength of boards caused by the proportion of small-sized chips in the core.

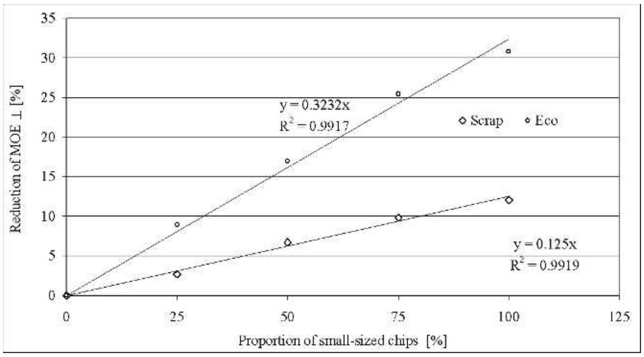

Figure 2.—A reduction in modulus of elasticity of boards caused by the proportion of small-sized chips in the core.

orientation resulting from the manual formation of the OSB-mat seem to have effectively masked the effect of changes occurring in the core. Similar dependencies were reported in a study by Hermawan et al. (2007). In their investigations, an increase in the resination rate of face layers either did not affect bending strength or caused only a slight increase in bending strength of boards for the longer axis. However, an increase in the resination rate of the core resulted in a significant increase in strength. Thus, it may be assumed that the expected negative effect of small-sized chips in the core was also masked by an increase in the resination rate of this layer.

A significant effect of the applied modification in the core may be clearly observed from an analysis of the bending strength and MOE for the shorter axis (Tables 3 through 5; Figs. 1 and 2). Substitution of 25 percent (wt/wt) of chips in the core resulted in a reduction of strength by 13 percent, irrespective of the type of small-sized chips, while for MOE it was by 3 and 9 percent for recycled chips and for chips originating from the comminuted particleboards, respectively. Boards containing only small-sized chips produced by comminuted solid wood in their core showed strength amounting to 65 percent initial strength, while Eco type boards had only 49 percent. Thus, strength of the latter is lower than the strength recommended by the standard EN 300 for OSB/3. In turn, considerably lower dynamics for changes were found for MOE, particularly with boards containing layer chips produced by comminuted solid wood in their core. This results from the unit mechanical strength of original chips, which was markedly lower than that of chips produced by comminuted particle board. A lower mechanical strength with these types of chips was clearly manifested in the analysis of internal bond. With an increase in the amount of small-sized chips, the internal bond for Eco type boards decreased markedly and at 100 percent substitution it was only 0.32 N/mm^2. Although the recorded value meets the requirements of the standard imposed for OSB/3, the value is 0.03 N/mm^2 lower than the stricter recommendations of the standard EN 312 (CEN 2003) for P2 boards. In turn, the strength of boards containing Scrap chips in their core was exceptionally high; 100 percent substitution of flakes in this layer resulted in only a minor change in strength (0.04 N/mm^2), which constituted a reduction in strength of approximately 5 percent of its initial value.

All the manufactured boards were characterized by a high thickness swelling property, almost two times higher than the recommended standard for OSB/3. However, no significant effect was found in either the amount or quality of applied chips, although slightly lower swelling values were recorded for Scrap boards. The application of the alkane emulsion for the control board (100% flakes in the core) resulted in an almost twofold reduction of swelling, and the obtained value was only slightly higher than the EN 300 requirements. Such a decrease in swelling of the control could have also been connected with the manual formation of the OSB-mat, which prevents the use of highly reactive curing agents applied at commercial scale production concentrations. Furthermore, the applied resination method does not guarantee such a uniform application of adhesive onto chips, as in the case with production lines. Recorded values meeting the requirements of the standard would most likely require an increase in the resination rate of boards.

Moreover, it was not possible in this study to manufacture boards exhibiting the recommended moisture resistance after the boiling test for the adopted resination rate. Most boards were destroyed during the boiling test itself, while those remaining showed negligible strength. Thus, it seems that an increase in the resination rate by as much as 8 to 10 percent for these types of boards is inevitable, while the only other solution is to manufacture boards resinated with pMDI in the core. Moreover, not all applied MUPF resins will guarantee that the EN 300 requirements are met when both layers are resinated with this resin (Evers et al. 2008).

All boards, except for those containing 100 percent small-sized chips in the core, meet the requirements of the standard EN 13986 (CEN 2004) in relation to hygienic grade E1.

Concluding Remarks

From the tests conducted in this study, the applied OSB modification, consisting of a partial or complete substitution of flakes with small-sized chips in the core, does not have a significant effect on bending strength or MOE (determined in the longer axis of boards) irrespective of the type and amount of small-sized chips used in the core. In turn, significant changes were found for such properties as bending strength and MOE determined in the smaller axis. OSB containing chips from comminuted particle boards displayed significant changes in internal bond strength. However, with our applied pressing parameters, boards containing up to 75 percent small-sized chips in the core exhibited relatively high mechanical property values. Using MUPF resin at the adopted resination rates did not enable manufacture of boards that could withstand the boiling test conditions. However, we conclude that the manufacture of OSB containing small-sized chips in the core produced using comminuted wood materials exhibited properties corresponding to at least OSB/3 resinated with MUPF/pMDI or pMDI only.

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Literature Cited

Barnes, D. 2000. An integrated model of the effect of processing parameters on the strength properties of oriented strand wood products. *Forest Prod. J.* 50(11–12):33–42.

Barnes, D. 2001. A model of the effect of strand length and stand thickness on the strength properties of oriented wood composites. *Forest Prod. J.* 51(2):36–46.

Barnes, D. 2002. A model of the effect of fines content on the strength properties of oriented strand composites. *Forest Prod. J.* 52(5):55–60.

Brinkmann, E. 1979. OSB-Platten, ihre Eigenschaften, Verwendung und Herstellungstechnologie. *Holz Roh- Werkst.* 37:139–142.

Bücking, C. 1977. Bison OSB neuer Spanplattentyp mit gerichteten Eigenschaften. *Holz Roh- Werkst.* 35(3):1.

Chen, S., C. Du, and R. Wellwood. 2008. Analysis of strand characteristics and alignment of commercial OSB panels. *Forest Prod. J.* 58(6):94–98.

Ehrentreich, W. 1980. OSB—das grosse Brett aus der Plattenküche. Seit über einem Jahr laeuft in Bevern die erste Produktionsanlage für grossformatige Platten mit richtungsorientierten Langspaenen. *Holz-Zentralblatt* 124:3–7.

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

European Committee for Standardization (CEN). 1993b. Particleboards and fibreboards. Determination of swelling in thickness after immersion in water. EN 317. CEN, Brussels.

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

European Committee for Standardization (CEN). 1994. Wood-based panels. Determination of formaldehyde content. Extraction method called the perforator method. EN 120. CEN, Brussels.

European Committee for Standardization (CEN). 1999a. Wood-based panels. Determination of density. EN 323. CEN, Brussels.

European Committee for Standardization (CEN). 1999b. Particleboards. Determination of moisture resistance. Part 1: Boil test. EN 1087-1. CEN, Brussels.

European Committee for Standardization (CEN). 2003. Particleboards—Specifications. EN 312. CEN, Brussels.

European Committee for Standardization (CEN). 2004. Wood-based panels for use in construction. Characteristics, evaluation of conformity and marking. EN 13986. CEN, Brussels.

European Committee for Standardization (CEN). 2006. Oriented strand boards (OSB). Definitions, classification and specifications. EN 300. CEN, Brussels.

Evers, L. B., R. A.T. M. Benthem, J. M. J. Mattheij, J. G. G. Gomez, and J. A. A. Vermeulen. 2008. Oriented strand boards. US patent 7,422,787.

Fakhri, H. R., K. E. Semple, and G. D. Smith. 2006a. Permeability of OSB. Part I. The effects of core fines content and mat density on transverse permeability. *Wood Fiber Sci*. 38(3):450–462.

Fakhri, H. R., K. E. Semple, and G. D. Smith. 2006b. Transverse permeability of OSB. Part II. Modeling the effects of density and core fines content. *Wood Fiber Sci*. 38(3):463–473.

Hermawan, A., T. Ohuchi, R. Tashima, and Y. Murase. 2007. Manufacture of strand board made from construction scrap wood. *Resour. Conserv. Recycl*. 50(4):415–426.

Jastrząb, J. 2008. Die Eigenschaften der OSB–Platten in der Abhängigkeit von der Holzspangeometrie in der Mittelschicht. *Ann. WULS - SGGW Forestry Wood Technol*. 65:136–139.

Keiser, J. 1987. OSB-Entwicklung in Europa. *Holz Roh- Werkst*. 45(10): 405–410.

Lee, O. L. and P. M. Tahir. 2003. Effects of fine particle content on the properties of five-layered oriented strand board. Unedited version of a paper submitted to the XII World Forestry Congress, 2003, Québec, Canada. http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0692-A2.HTM.

Mirski, R. 2009. The effect of variable environmental conditions on dimensional changes in thin wood-based materials. Part I. Absorption changes. *Electron. J. Polish Agric. Univ*. 12(4), #04. http://www.ejpau.media.pl/volume12/issue4/art-04.html.

Nishimura, T., J. Amin, and M. P. Ansell. 2004. Image analysis and bending properties of model OSB panels as a function of strand distribution, shape and size. *Wood Sci. Technol*. 38(4):297–309.