APPLICABILITY OF STRAND SUBSTITUTION IN THE CORE OF OSB

Radosław Mirski and Dorota Dziurka*

Strand substitution was evaluated for the core of OSB with chips produced by grinding of recycled particleboards and wood waste. All the boards manufactured under laboratory conditions having a share of small chips in the core had high mechanical parameters, thus meeting the requirements of the standard for OSB/3. No significant effect was found of the applied modification of the core on bending strength or modulus of elasticity (MOE) determined for the longer axis. In turn, such properties as modulus of rupture (MOR) and MOE, determined for the shorter axis, as well as internal bond (IB) were rapidly reduced. In the case of boards containing 100% recycled chips in the core, a reduction was found in values of MOR, MOE, and IB by 45%, 30%, and 45%, respectively. In turn, the application of small chips, which previously had not been resinated, makes it possible to manufacture boards with internal bond lower by only 30%, even at the 100% substitution. Application of recycled chips produced by grinding of the P2 type particleboard did not make it possible to manufacture boards meeting the requirements of the standard after the boiling test, irrespective of the amount of small chips added to the core. Boards containing in their core small chips, which previously had not been resinated, had much better properties in this respect, since only in case of 100% substitution the manufactured boards exhibited internal bond after the boiling test lower than the requirements of the standard EN 300.

Key words: OSB; Mechanical properties; Strand; Chips

*Contact information: Poznań University of Life Sciences, Department of Wood-Based Materials, Wojska Polskiego Str. 28, 60-637 Poznań, Poland; * Corresponding author: ddziurka@up.poznan.pl*

INTRODUCTION

Increasingly broader uses of OSB within the construction sector have contributed to a consistent increase in its production. Due to its very good mechanical strength and resistance to the action of changeable environmental conditions, OSB, as a fairly cheap material, is found to be highly competitive in relation to plywood, replacing this material in applications previously reserved only for plywood. However, also OSB is now facing competition from materials with similar physico-mechanical properties, but a markedly lower price. Such substitutes of OSB as MFP (Multi Function Panel) or P5 particleboard are cheaper by 20% and 25%, respectively, than OSB.

High physico-mechanical properties of OSB are provided mainly by strands used in its production, or rather by their geometry (Geimer et al. 1975; Mayers 2001). Their shape, and at the same time their size, should facilitate their easy orientation and the transfer of possibly the highest number of properties from the advantageous characteristics of natural wood. Thus, it seems that the longer and the wider a strand is (at the simultaneous maintenance of an adequate slenderness ratio), the better it is. However, an increase in strand length over 120 mm does not cause a significant increase in bending strength or modulus of elasticity and static properties (Barnes 2001; 2000). Thus, strands of the following dimensions: length 75 to 120 mm, width 20 to 30 mm, and thickness 0.3 to 0.7 mm, are used most typically (Keiser 1987; Chen et al. 2008). The application of strands with the above-mentioned dimensions requires in their production the use of wood in the non-comminuted form, i.e., wood of better quality and thus much more expensive than that used in the production of particleboards. Although thanks to the application of strands of a bigger specific surface it is possible to reduce the amount of applied adhesive even by as much as over 50% in relation to particleboard, it is the price of the wood that determines the price of the final product.

The primary adhesives in OSB production include phenol-formaldehyde resins (PF), used mainly in the USA (Sellers 2001), and melamine-urea-phenol-formaldehyde resin (MUPF) or polymeric Methylene Diphenyl Diisocyanate (pMDI) applied in Europe. Of these, particularly pMDI is highly appreciated by board producers, because it allows them to achieve high parameters in boards at relatively low resination rates. Moreover, boards resinated in this way not only belong to hygienic class E0, but also their production itself is characterized by a higher hygienic standard of work stations (Vangronsveld et al. 2010).

It is well known from industrial practice that when producing strands, as much as up to 20% of fine fractions may be left over. Already in the early 1980's it was observed that these chips may be combusted or added to chips in the core (Brinkmann 1979; Ehrentreich 1980). Generally only the fraction below 1 mm is used for combustion, while the other chips are used in the production processes. On the one hand, small chips deteriorate mechanical properties of boards (Nishimura et al. 2004); on the other hand, they improve the profitability of the production process. In turn, the use of recycled wood for this purpose not only should improve the economic parameters of the production process, but it also should enable the environmentally-friendly aspects of recycling. For the above mentioned reasons it was decided in this study to investigate whether and to what degree it is possible to substitute strands in the core of OSB with small chips coming from comminuted unrefined particleboards.

MATERIAL AND METHODS

Commercial pine strands were used in the manufacture of OSB. Small chips to be used in the core were produced by grinding in a laboratory mill. Unfinished particleboards originally designed for furniture production (type P2) were the source material. Control boards were prepared that also contained such small chips, except that those chips were obtained from quality wood waste. A pretreated batch of small chips was sieved at mesh size of 1 x 1 mm in order to separate dust and fine fractions. The fraction composition of chips used in these tests is presented in Fig. 1. In both types of chips, fractions of 1 mm and 2.5 mm predominated, amounting to 83% and 90% total weight of chips produced by grinding of particleboards and timber.

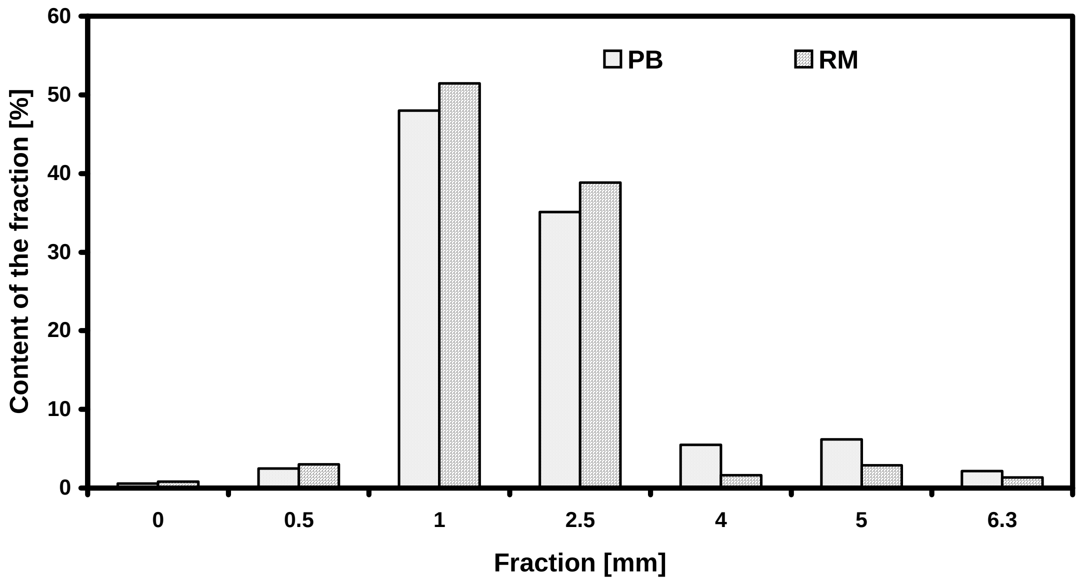

Fig. 1. Fractional composition of small chips (PB = chips produced by grinding of particleboard; RM = produced by grinding of wood waste)

It was assumed that the proportion of small chips would range from 0% to 100% with a 25% increment in chip weight in proportion in the core. pMDI was used as a bonding agent. Because manufactured OSB should have physico-mechanical properties similar to commercial OSB/3 board, it should thus be produced under conditions as close to the industrial practice as possible; the specific pressing parameters are given in Tab. 1. As shown from the presented data, the resination rate (content of the resin) of both the core and the face layers was identical in case when the core contained 100% strands. In turn, resination of the core containing small chips was increased by 0.7 kg/m^3, in proportion to the amount of small chips introduced, in order to compensate for the increase in specific surface.

Table 1. Characteristics of the Pressing Process of OSB

Proportion of small-sized chips	Content of the resin		Press time	Platen temp.	Pressure
	face	core			
(%)	($kg·m^{-3}$)		($s·^{-1}mm$)	(°C)	($N·mm^{-2}$)
0	15.77	15.77	15	200	2.5
25	15.77	16.47	15	200	2.5
-	-	-	-	-	-
100	15.77	18.57	15	200	2.5

Pre-treated batches of small chips to be used in the core and face layers were resinated in a laboratory small-speed gluing machine, and next the cake was formed manually, trying to maintain orientation directions as best as possible.

Under laboratory conditions for each variant, 3 three-layer OSB panels, of 15 mm in thickness and density of 600 kg/m^3, were manufactured from such prepared material. A set of boards (5 x 3 pieces) was produced each time for each series. Individual board series were pressed at a 1-week interval, and for this reason control boards were manufactured for each of them separately. Produced boards were conditioned under standard conditions for 4 weeks. For each variant a total of 21 samples of 50 x 350 mm were obtained from OSB panels for the longer and shorter axes to be used for analyses of MOR and MOE, as well as 60 samples (with 20 for each test) of 50 x 50 mm to be tested for the other properties.

Tests were conducted on OSB in accordance with the respective standards to determine such properties as:

- Bending strength (modulus of rigidity MOR) and modulus of elasticity MOE in accordance with EN 310,
- Internal bond IB in accordance with EN 319,
- Water resistance determined by the V-100 test in accordance with EN 1087-1,
- Swelling in thickness after 24 h in accordance with EN 317.

RESULTS AND DISCUSSION

Properties of OSB containing small chips in their core as a substitute for strands are presented in Tables 2 and 3. As shown from these data, all the boards were characterized by very high bending strength and modulus of elasticity determined for the longer axis. Values of these properties were similar to those of control boards and they were similar, irrespective of the proportion of small chips in the core. Slight fluctuations in these properties may result either from the quality of strands in the face layer found at the site of the direct impact of the thrust (rupture) during the determination of these values and/or also the action of external conditions during the formation of the cake as well as the degree of strand orientation. A marked effect of small chips in the core could be observed when analyzing bending strength and modulus of elasticity for the shorter axis. In that case boards containing 25% small chips exhibited strength lower by approx.-imately 16%, and in those containing 100% such chips it was already over by 45%. Moreover, in case of boards containing 100% small chips coming from the comminution of timber, the recorded values of bending strength and modulus of elasticity were as required by the standard EN 300. In turn, slightly higher values of MOR and MOE for this axis were recorded for OSB containing in their core chips coming from the comminution of particleboards. This pertains mainly to boards with higher amounts of small chips in the core (75% and 100%), i.e., those in which the final strength values will be determined primarily by the quality of small chips. It seems that one of the causes of such behaviour of these boards may be a lower absorbability of the adhesive by previously resinated chips, thanks to which the area of glue lines between chips is increased. However, this is not contradicted by the fact that internal bond is clearly higher for boards containing previously unresinated chips. As it is commonly known, strength of particleboards resinated with urea-formaldehyde resin rarely exceeds 0.4 N/mm^2; thus, it is mainly the urea glue line, strengthened with pMDI only on the surface that is destroyed. The weakness of urea-formaldehyde glue lines was clearly confirmed by the results of internal bond testing after the boiling test. In such a case boards containing a 25% share of small chips still exhibited relatively high strength after the V100 test, although it was lower than the requirement of the standard, imposing the value of 0.11 N/mm^2. At higher amounts they were destroyed already during the boiling process itself. In contrast, OSB variants containing in their core previously unresinated small chips, except for their 100% share, met the requirements of the standard in this respect. Values of the V100 testing recorded for boards with 25% and 50% shares of such chips were even higher by 0.09 N/mm^2 and 0.03 N/mm^2, respectively, than the requirements of the standard.

Table 2. Characteristics of Tested OSB – Containing in the Core Chips Produced by Grinding of Particleboard

Property	Testing method	Unit	Proportion of small-sized chips in the core U [%]									
			0		25		50		75		100	
ρ	EN 323	(kg ·m^{-3})	610	*10**	610	*20*	605	*15*	600	*16*	610	*15*
G	EN 317	(%)	29.3	*2.0*	31.1	*1.6*	32.9	*2.2*	27.3	*2.7*	28.4	*1.5*
MOR II	EN 310	(N·mm^{-2})	38.2	*3.2*	38.8	*5.6*	39.2	*4.3*	38.3	*3.4*	36.5	*3.7*
MOR ⊥	EN 310	(N·mm^{-2})	22.4	*1.6*	19.2	*1.7*	16.7	*1.7*	15.2	*0.9*	12.3	*0.8*
MOE II	EN 310	(N·mm^{-2})	6700	*400*	6710	*590*	6580	*430*	6690	*210*	6750	*470*
MOE ⊥	EN 310	(N·mm^{-2})	2310	*250*	2140	*90*	1950	*230*	1820	*200*	1610	*120*
IB	EN 319	(N·mm^{-2})	0.88	*0.06*	0.75	*0.05*	0.67	*0.08*	0.58	*0.06*	0.49	*0.03*
V100	EN 1087-1	(N·mm^{-2})	0.23	*0.016*	0.11	*0.007*	0.04	*0.004*	0.01	*0.018*	-	-
* standard deviation												

Table 3. Characteristics of tested OSB - containing in the core chips produced by grinding of wood waste

Property	Testing method	Unit	**Proportion of small-sized chips in the core U (%)**									
			0		25		50		75		100	
ρ	EN 323	(kg ·m^{-3})	600	*12*	626	*20*	595	*20*	620	*15*	600	*10*
G	EN 317	(%)	30.4	*1.3*	31.5	*2*	21.6	*1.6*	27.6	*1.7*	22.8	*1.0*
MOR II	EN 310	(N·mm^{-2})	41.4	*3.1*	42.9	*2.9*	41.8	*3.8*	44.1	*4.1*	42.9	*4.3*
MOR ⊥	EN 310	(N·mm^{-2})	23.2	*2.4*	19.2	*1.7*	17.1	*1.4*	14.3	1.3	10.2	*0.8*
MOE II	EN 310	(N·mm^{-2})	7000	*380*	6960	*250*	6920	*430*	7150	*320*	7020	*230*
MOE ⊥	EN 310	(N·mm^{-2})	2370	*170*	2120	*180*	1860	*200*	1690	*150*	1400	*140*
IB	EN 319	(N·mm^{-2})	0.86	*0.05*	0.78	*0.09*	0.71	*0.06*	0.69	*0.06*	0.59	*0.02*
V100	EN 1087-1	(N·mm^{-2})	0.29	*0.09*	0.22	*0.013*	0.16	0.010	0.13	*0.009*	0.09	*0.009*

All the OSB variants manufactured under laboratory conditions were characterized by a relatively high swelling in thickness. Even the application of previously resinated chips, most probably resinated also with the use of hydrophobic agents, did not improve this parameter. A characteristic property of the manufactured OSB, irrespective of the type of small chips, was the practically linear dependence of such properties as MOR and MOE determined for the shorter axis, as well as IB, on the percentage shares of small chips in the core (Table 4). Such a high dependence of these properties on the share of small chips in the core makes it possible with high probability to estimate these properties for any selected amount of small chips. However, it needs to be remembered that with an increase in the proportion of small chips the resination rate in this layer also increased. As was already mentioned, bending strength and modulus of elasticity determined for the shorter axis decreased much more intensively with an increase in the share of fine fractions in the core in case of boards with an addition of chips, which had not been previously resinated. In contrast, internal bond was reduced more intensively when recycled chips were added to the boards.

Table 4. Regression Results on *X-U* (for $X \in$ {MOR, MOE, IB} Relationship for OSB with a Linear Model ($X = a_0 + a_1U$)

Regresion coefficients	Unit	Numerical value					
		X					
		MOR – PB	MOR – RM	MOE - PB	MOE – RM	IB – PB	IB - RM
a_0	($N \cdot mm^{-2}$)	22.00	22.98	2310	2362	0.864	0.852
a_1	($N \cdot mm^{-2} \cdot \%^{-1}$)	-0.0968	-0.1236	-6.88	-9.48	-0.0038	-0.0027
R^2	-	0.9877	0.9882	0.9964	0.9954	0.9926	0.9940

CONCLUSIONS

The results from the conducted tests demonstrated that all boards manufactured under laboratory conditions with a share of small chips in the core were characterized by high mechanical parameters, thus meeting the requirements of the standard for OSB/3. No significant effect was found of the applied modification of the core on bending strength or modulus of elasticity determined for the longer axis. In turn, such properties as MOR and MOE, determined for the shorter axis, as well as IB were rapidly reduced. In the case of boards containing 100% recycled chips in the core, a reduction was found in values of MOR, MOE, and IB by 45%, 30%, and 45%, respectively. In turn, the application of small chips, which previously had not been resinated, made it possible to manufacture boards with internal bond lower by only 30% even at the 100% substitution. Moreover, linear dependencies observed for these properties were characterized by high values of goodness of fit R^2. The application of recycled chips produced by grinding of the P2 type particleboard did not make it possible to manufacture boards meeting the requirements of the standard after the boiling test, irrespective of the amount of small chips added to the core. However, it seems that already a reduction of the share of these chips below 25% or a slight increase in resination rates should make it possible to manufacture boards meeting these requirements. Boards containing in their core small chips, which previously had not been resinated, had much better properties in this respect, since only in case of 100% substitution the manufactured boards exhibited internal bond after the boiling test lower than the requirements of the standard EN 300.

ACKNOWLEDGMENTS

This study was financed by the Polish Ministry of Science and Higher Education, grant number N N309 428138.

REFERENCES CITED

Barnes, D. (2000). "An integrated model of the effect of processing parameters on the strength properities of orientem stand wood products," *For. Prod. J.* 50 (11-12), 33-42.

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

Brinkmann, E. (1979). "OSB-Platten, ihre Eigenschaften, Verwendung und Herstellungstechnologie," *Holz als Roh- und Werkstoff* 37, 139-142.

Chen, S., Du, C., and Wellwood, R. (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 Seit über einem Jahr laeuft in Bevern di erste Produktionsanlage für grossformatige Platten mit richtungsorientierten Langspaenen, " *Holz-Zentralblatt*, 124.

Geimer, R. L., Montrey, H. M., and Lehmann, W. F. (1975). "Effects of layer characteristics on the properties of three-layer particleboards," *Forest Prod. J.* 25(3), 19-29.

Keiser, J. (1987). "OSB-Entwicklung in Europa," *Holz als Roh-und Werstoff*, 10.

Mayers, K. L. (2001). "Impact of strand geometry and orientation on mechanical properties of strand composites," *Thesis Ms. Sc. In Civil Engineering, Washington State University*.

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

Vangronsveld, E., Berckmans, S., Verbinnen, K., Van Leeuw, C., and Bormans, C. (2010). "Isocyanate and total inhalable particulate air measurements in the European wood panel industry," *Int. J. Hyg. Environ. Health* 213(6), 475-88.

Sellers, T. Jr. (2001). "Wood adhesive innovations and applications in North America," *Forest Prod. J.* 51(6), 12-22.

Article submitted: February 15, 2011; Peer review completed: April 15, 2011; Revised version accepted: June 27, 2011; Published: July 1, 2011.