THE EFFECTS OF ADHESIVE RATIO AND PRESSURE TIME ON SOME PROPERTIES OF ORIENTED STRAND BOARD

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This study was carried out to determine the effects of adhesive ratio and pressure time on thickness swelling (TS), internal bond (IB), modulus of rupture (MOR), and modulus of elasticity (MOE) properties of oriented strand board (OSB). For this purpose, 80 mm long strands made of Scots pine (*Pinus sylvestris* L.) were bonded with phenol-formaldehyde resin at three different ratios (3, 4.5, and 6%) to produce three-layer cross-aligned OSBs. Strands used for the production of OSB panels were made up 40% of core layer and 60% of outer layers. The panels were pressed for three different press times, from 3, 5, to 7 minutes, under 0.4 MPa pressure, aiming for a target density of 0.70 g/cm3. TS, IB, MOR, and MOE properties of OSB panels were evaluated according to the standards (TSE EN 117-319-310). Results showed that MOR and MOE values were changed in the ranges 25.31 to 42.27 N/mm^2, and 2848.90 to 6545.63 N/mm^2, respectively. Also, the results showed that as adhesive ratio and pressure time increased, the TS, MOR, and MOE values increased too.

Key words: Oriented strand board; Strand alignment; Phenol-for maldehyde; Physical properties; Mechanical properties.

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INTRODUCTION

Timber resources have declined during the past several decades. Available timber is now smaller in diameter and lower in quality. One response to the decreasing supplies of high quality wood is an increase in demand for reconstituted wood products in which previously used smaller species or mill residues are processed into high-value wood composite materials (McKeever 1997). According to Maloney (1996), OSB panels are made of compressed strands lined up and arranged in three to five layers that are oriented at right angles to each other. And in some cases, the strands used in core layers are randomly oriented. OSB is generally similar to three-layered symmetric laminate. The outer layers of strands are orientated with the long dimension, and the inner layers are orientated at right angles to the outer layer (Green et. all. 1998).

Oriented strand boards are a relatively new kind of wood-based panels that are defined in the European Standard. Particle boards are classified depending on the size and orientation of their components (Rebollar et. all. 2007). Oriented strand board (OSB) has been produced as a structural panel material, substituting for softwood plywood in North America since the early 1980s (Spelter et.all.1997). The primary benefits of OSB are its equivalent mechanical properties and substantially lower cost compared to the other structural plywood. They are more commonly used in the building sector as construction panels, both for structural purposes and as ceiling coverings (Lam 2001).

The most distinguishing difference between OSB and waferboard, which is the predecessor of OSB, is the high degree of orientation in the face strands. This orientation serves to improve the mechanical properties of the panel in the direction of alignment. As a result, the panel has greater elastic modulus in the longitudinal direction. It is apparent that the orientation of the principal material directions of the flakes will greatly influence the mechanical and physical properties of the board (Harris et. all 1982). Geimer (1976) stated that small increases in degree of alignment can result in substantial increases in bending strength and stiffness of flake boards (Geimer 1976).

One of the most important factors affecting the properties of OSB is adhesive type. Phenolic adhesives have a reputation for providing strong and durable bonds in wood composites. Phenolic based resins including urea-formaldehyde and phenol-formaldehyde are the two most commonly used binders in the wood composites industry (Steinmetz et. all.1974).

Avramidis and Smith (1989) and Tang et al. (1984) both stated that mechanical properties of OSB increased as resin ratio increased from 4 to 5 then 6 %. In addition, water absorption, thickness swelling, and linear expansion properties improved with increasing resin ratio. Generalla et al. (1989) stated that increasing liquid PF resin content generally improved the mechanical properties of the commercial southern OSB after 48-h water-soak and 48-h water-soak then reconditioned at normal standard condition. Under normal conditions these improvements were not statistically significant. Deppe and Hasch (1990) used foamed melamine-UPF (aminoplast) resins in OSB manufacturing with Scots pine strands. The TS of the boards was reduced by approximately 50%. IB strength was satisfactory, but bending strength values were inadequate because of the unsatisfactory strength of the foam. Winistorfer and Dicarlo (1988) investigated the effect of resin (absolute solid resin without water) nonvolatile content (50.8, 54.8, and 58.8%) on dimensional stability. Increasing resin nonvolatile content yielded significantly greater TS values due to inadequate resin distribution.

Many parameters affect the final mechanical and physical properties of OSB. Nearly all factors interact with each other in one way or another. Consequently, each factor cannot be thought of as an individual entity that can be manipulated to control panel properties. The situation is rather complex and necessitates a more complete understanding of the entire process before any improvement can be made (Basturk 1999).

The most important parameters affecting the properties of OSB are adhesive ratio and pressing time. Two factors, which are the most important of these, are pressing time and adhesive ratio relative to wood solids. The determination of the effects of these factors on the physical and mechanical properties of panels is very important for manufacturing of OSBs. In this study the aim was to evaluate the effects of production conditions of OSB panels such as pressing time and adhesive ratio on thickness swelling (TS), internal bond (IB), modulus of rupture (MOR), and modulus of elasticity (MOE) of OSB.

MATERIAL AND METHODS

Mature Scots pine wood (*Pinus sylvestris* L.) was used in the production of the oriented strand boards (OSB). The strands dimension in usage was approximately 80 mm long, 20 mm wide, and 0.7 mm thick. First, the wood strands were dried to 3% moisture content before adhesive was sprayed on them for three minutes. Then, adhesive material without wax, a solid content of 47% liquid phenol- formaldehyde resin, was applied in 3, 4.5, and 6 percent ratios based on the weight of oven dry wood strands. Viscosity of the adhesive was 14 000 ± 3000 mPa s at 25°C.

The press periods and press pressure were 3, 5, and 7 minutes under the 0.4 MPa press pressure, respectively. The shelling ratio was 40% for core layer and 60% for face layer, and density of the boards was aimed at 0.70g/cm^{3}density. OSB panels, which were dimensioned as 56x56x1.2 cm, were made for experiments, in the nine conditions. They were 27 in total and three for each condition. Hand formed mats were pressed in a hydraulic press. These panels were labeled from A to I. All mats were pressed under automatically controlled conditions at 182±3 ºC. After pressing, the boards were conditioned to constant weight at 65±5% relative humidity and at a temperature of 20±2 ºC until they reached stable weight (TS 642 1997). Fifteen samples were taken from boards to perform the TS, IB, MOR, and MOE values tests of panels.

In measurement of IB, MOR and MOE values, a Zwick/Roell Z050 universal test device with capacity of 5000kg and measurement capability of 0.01Newton in accuracy was used. In testing, the loading mechanism was operated with a velocity of 5 mm/min.

Data for each test were statistically analyzed. The analysis of variance (ANOVA) was used ($\alpha<0.05$) to test for significant difference between factors. When the ANOVA indicated a significant difference among factors, the compared values were evaluated with the Duncan test to identify which groups were significantly different from other groups.

RESULTS AND DISCUSSION

The density and moisture content values of OSBs were determined according to the related standards (TS-EN 323 1999; TS-EN 322 1999). The average density and moisture content of panels were obtained as 0.73 g/cm^2 and 7.4%, respectively. It was found out that the aimed and acquired values related to density and moisture were within the ranges specified in the standards.

The average and standard deviation of the values of thickness swelling (TS) and internal bond (IB) are given in Table 1, and the modulus of rupture (MOR), modulus of elasticity (MOE) of produced panels are also available as flexure parallel and flexure perpendicular in the table.

It was found that the thickness swelling rate varied between 15.14% and 28.16% after the sample had been kept in water for 24 hours. And also there was a critical increase after increasing the adhesive level and pressing duration (Wang et al. 2000).

Table 1A. Summary of the Test Results of the Specimens

Panel Type	Adhesive ratio (%)	Press time (Minute)	Density of panels (g/cm^3)	TS (%) 24 h.		IB (N/mm^2)		MOR (N/mm^2)			
								Flexure Parallel		Flexure perpendicular	
				Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
A	3	3	0.72	28.16	1.61	0.26	0.08	25.31	1.49	15.99	0.70
B	3	5	0.70	25.87	1.04	0.29	0.05	27.89	2.43	20.21	2.19
C	3	7	0.73	25.13	2.37	0.36	0.12	30.58	2.99	21.15	1.18
D	4.5	3	0.73	22.63	2.29	0.42	0.09	32.07	1.62	21.74	2.22
E	4.5	5	0.75	22.30	2.22	0.44	0.05	32.24	1.82	23.80	2.12
F	4.5	7	0.71	21.50	2.04	0.45	0.11	32.90	2.48	22.65	2.10
G	6	3	0.73	20.17	3.60	0.49	0.09	33.73	1.95	23.56	2.38
H	6	5	0.75	15.84	1.66	0.53	0.06	35.26	3.73	24.38	1.87
I	6	7	0.76	15.14	1.23	0.60	0.21	42.27	2.63	28.28	3.35

Table 1B. Summary of the Test Results of the Specimens

Panel Type	Adhesive ratio (%)	Press time (Minute)	MOE(N/mm^2)			
			Flexure Parallel*		Flexure Perpendicular*	
			Mean	Std. Dev.	Mean	Std. Dev.
A	3	3	4594.99	801.50	2848.90	496.93
B	3	5	4406.91	474.22	3206.40	596.77
C	3	7	4674.43	335.58	3110.36	256.37
D	4.5	3	5285.18	608.69	3483.45	437.95
E	4.5	5	5088.02	358.47	4172.18	293.95
F	4.5	7	4852.00	645.53	3854.97	321.52
G	6	3	4877.39	784.23	3569.63	693.66
H	6	5	5802.16	627.95	3674.84	479.22
I	6	7	6545.63	1277.72	3990.22	424.25
Flexure parallel: Face orientation along the span; Flexure perpendicular: face orientation perpendicular to the span.						

Internal bond is one of the most common tests, and it was used as a determiner of the inner bond quality of panels. It was found that the adhesive resistance values of the test samples varied between 0.26 N/mm^2 and 0.60N/mm^2. The lowest value for internal bond of produced panels was 0.26 N/mm^2 (3% adhesive ratio and 3 minutes press time). When the press time was increased from 3 minutes to 7 minutes and adhesive ratio from 3% to 6%, the internal bond increased from 0.26 N/mm^2 to 0.60 N/mm^2. It was observed that the adhesive resistance values of OSB layers which were produced in 12.7 mm thickness and in 625 kgm^{-3} density by using phenol formaldehyde adherent of 4% varied between 25.7 and 38.2 psi. (Brochmann et al. 2004). It was also reported that in OSB layers produced by using phenol formaldehyde, as pressing duration increased, the swelling rate in thickness decreased and tensile strength perpendicular to layer surface also increased (Ohlmeyer et al. 1999). MOR and MOE values were determined according to flexure parallel and flexure perpendicular of the produced panels. While the lowest MOR value of panels which were produced at 3% adhesive ratio and 3 minutes press time was calculated as 15.99 N/mm^2, the highest value was obtained in 6% adhesive ratio and 7 min. press time conditions, calculated as 42 N/mm^2. In a similar study, it was found that by increasing the adhesive level from 5% to 8%, bending pressure value was increased by about 10.27% in flexure parallel with the length of the layers (Okino et al. 2004).

According to the variance analysis, the effects of the adhesive ratio and pressing time on TS, IB, MOR, and MOE values were statistically significant. Duncan test results conducted to determine the importance of the differences between the groups are given in Table 2A-B.

Table 2A. Duncan test Results

Source		TS (%)		IB (N/mm^2)		MOR (N/mm^2)			
						Flexure Parallel*		Flexure Perpendicular*	
		Mean	HG	Mean	HG	Mean	HG	Mean	HG
Adhesive ratio (%)	3	26.38	A	0.30	A	27.92	A	19.11	A
	4.5	22.14	B	0.43	B	32.40	B	22.72	B
	6	17.05	C	0.53	C	37.08	C	25.40	C
Pressing time (minutes)	3	23.65	A	0.39	A	30.36	A	20.42	A
	5	21.33	B	0.41	A	31.79	B	22.79	B
	7	20.58	C	0.46	B	35.24	C	24.02	C
Flexure parallel: Face orientation along the span; Flexure perpendicular: face orientation perpendicular to the span.									

Table 2B. Duncan test Results

Source		MOE (N/mm^2)			
		Flexure Parallel		Flexure Perpendicular	
		Mean	HG	Mean	HG
Adhesive ratio (%)	3	4558.77	A	3055.21	A
	4.5	5075.06	B	3744.90	B
	6	5741.72	C	3836.86	B
Pressing time (minutes)	3	4919.18	A	3300.66	A
	5	5099.03	A	3684.47	B
	7	5357.35	B	3651.84	B

According to the results of the statistical analysis, the adhesive ratio and pressing time were found to have significant effects on the TS, IB, MOR, and MOE properties of OSB panels. The increase of adhesive ratio from 3 to 6% improved the TS, IB, MOR, and MOE ($p<0.05$). In addition, the increase of pressing time from 3 to 7 minutes resulted in a better thickness swelling, internal bond, modulus of rupture, and modulus of elasticity properties of OSB panels.

CONCLUSIONS

As the adhesive ratio and press time increased, values of thickness swelling, internal bond, modulus of rupture, and modulus of elasticity improved. Although the highest MOR and IB values were obtained from I samples as 42.27 and 0.60 N/mm^2, the lowest values of those were obtained from A samples as 15.99 and 0.26 N/mm^2, respectively. Also, the results showed that the values of modulus of elasticity changed between 2848.90 and 4172.18 N/mm^2. Based on EN standards, 9-18 N/mm^2, and 1200-2500 N/mm^2 are minimum requirements for modulus of rupture and modulus of elasticity of oriented strand board panels for general uses and furniture manufacturing, respectively. While modulus of rupture and modulus of elasticity values of the panels identified as A, B, and C possessed expected properties of general-purpose panels, those acquired from panels D, E, F, G, H, and I were suitable for carrying load under dry and humid weather conditions. Moreover, it was found that the thickness swelling after keeping specimens in water for 24 hours varied between 15% and 28%. When thickness swelling results were compared to related standards, the thickness swelling of panels A, B and C were judged to be high and it can be asserted that this resulted from an insufficient pressing duration for hardening of the adhesive (3 minutes). However, it was found out that thickness swelling determined for panels D, E, F, and G panels were sufficient for the general purpose and furniture sectors. Besides, the values determined for thickness swelling of H and I panels were suitable to carry load under dry conditions. So, if the OSB panels are to be used for load bearing applications in building, the adhesive ratio and pressing time should not be less than 6% and 5 minutes, respectively.

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