EFFECT OF MOISTURE ON BENDING AND BREAKING RESISTANCE OF COMMERCIAL ORIENTED STRANDBOARDS[1]

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ABSTRACT

This is a short addendum to an earlier paper (Wu and Suchsland 1997) on bending resistance (E·I) and breaking resistance (R·S) of commercial oriented strandboard (OSB). It is shown that for a moisture content (MC) change from 4 to 24%, the combined effect of increased MC and thickness swelling led to an average E·I loss of 37% in the parallel direction and 51% in the perpendicular direction; and to an average R·S loss of 31% in the parallel direction and 43% in the perpendicular direction. Predictive equations expressing E·I and R·S as functions of moisture content were established for various products.

Keywords: Design, flakeboard, stiffness, strength, thickness swelling.

INTRODUCTION

In an early publication, Wu and Suchsland (1997) discussed the effect of moisture on the flexural properties of commercial oriented strandboard (OSB). Modulus of elasticity (E) and modulus of rupture (R) as functions of moisture content (MC) and thickness swelling were reported for five-type commercial OSB products made of two wood species (aspen and southern pine). It has shown that, for an MC change from 4 to 24%, the combined effect of increased MC and thickness swelling led to an average E loss of 72% in the parallel direction and 83% in the perpendicular direction; and to an average R loss of 58% in the parallel direction and 67% in the perpendicular direction. The study clearly demonstrated that moisture-related swelling can significantly damage the integrity of commercial OSB products. Therefore, protection of OSB products from moisture uptake before and during use has some important practical significance in maintaining the quality and performance of OSB.

However, the paper did not include discussions on bending resistance—defined as a product of E and moment of inertia I, E·I, and breaking resistance—defined as a product of R and section modulus S, R·S. Since both I and S increase with specimen thickness, which increases with MC due to thickness swelling, relationships of E·I and R·S with MC would be of more interest to structural engineers (Knudson 1997).

The purpose of this paper was to provide a short addendum to the previous paper and to establish relationships between E·I, R·S, and MC.

METHODS

The experimental procedures are given in detail in Wu and Suchsland (1997) and are reviewed briefly. Five different commercial OSBs made of two wood species (aspen and southern pine) for three major applications (sheathing, floor underlayment, and I-beam web) were selected for the study. Two panels (122- × 122-cm × thickness) of each type of OSB, cut from two separate 122- by 244-cm

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TABLE 1. *Summary of MC, specific gravity, panel thickness, E·I and R·S in both parallel and perpendicular directions for the test panels.*

OSB[b]	MC (%)	Specific gravity[c]	Parallel thickness (cm)	E·I[d] (MPa cm^4)	R·S[e] (MPa cm^3)	MC (%)	Specific gravity	Perpendicular thickness (cm)	E·I (MPa cm^4)	R·S (MPa cm^3)
	5.1 (0.1)	0.64 (0.02)	1.09 (0.00)	4,276 (403)	48.1 (7.4)	5.3 (0.2)	0.68 (0.02)	1.09 (0.00)	1,743 (192)	33.4 (5.9)
	8.3 (0.1)	0.67 (0.04)	1.12 (0.00)	4,427 (543)	57.8 (5.9)	7.6 (0.1)	0.65 (0.02)	1.11 (0.00)	1,311 (119)	25.5 (2.7)
SPS	11.6 (0.3)	0.67 (0.02)	1.15 (0.00)	4,093 (348)	46.8 (7.8)	12.5 (0.2)	0.68 (0.01)	1.17 (0.00)	1,440 (119)	27.5 (4.8)
	14.0 (0.3)	0.67 (0.01)	1.19 (0.00)	3,756 (689)	43.1 (8.1)	14.0 (0.6)	0.65 (0.01)	1.19 (0.00)	1,269 (174)	27.0 (2.6)
	22.1 (0.4)	0.62 (0.04)	1.33 (0.01)	3,398 (567)	39.2 (2.9)	20.8 (0.2)	0.64 (0.04)	1.30 (0.00)	1,172 (139)	23.2 (3.6)
	5.3 (0.1)	0.69 (0.01)	1.02 (0.00)	3,859 (514)	60.1 (8.5)	5.3 (0.1)	0.73 (0.02)	1.02 (0.00)	1,585 (219)	34.5 (6.9)
	8.3 (0.4)	0.71 (0.01)	1.05 (0.00)	3,935 (391)	54.9 (4.3)	8.3 (0.4)	0.74 (0.01)	1.05 (0.00)	1,579 (222)	43.6 (5.1)
SPI	11.5 (0.2)	0.74 (0.03)	1.08 (0.00)	3,574 (340)	54.7 (4.1)	11.9 (0.3)	0.73 (0.03)	1.08 (0.00)	1,583 (161)	41.5 (3.8)
	13.9 (0.3)	0.72 (0.03)	1.10 (0.00)	3,320 (538)	54.7 (9.2)	14.1 (0.2)	0.74 (0.02)	1.10 (0.00)	1,195 (96)	29.5 (1.7)
	19.5 (0.5)	0.71 (0.02)	1.16 (0.01)	3,146 (218)	46.8 (5.2)	20.9 (0.4)	0.74 (0.02)	1.17 (0.00)	1,069 (173)	28.6 (3.3)
	5.3 (0.1)	0.63 (0.01)	1.52 (0.00)	12,447 (941)	86.8 (10.5)	5.2 (0.1)	0.65 (0.02)	1.52 (0.00)	4,795 (296)	58.5 (9.6)
	8.9 (0.5)	0.66 (0.02)	1.56 (0.01)	12,437 (959)	92.1 (9.7)	8.7 (0.5)	0.63 (0.04)	1.56 (0.01)	4,542 (292)	63.0 (8.3)
SPF	13.1 (0.3)	0.69 (0.03)	1.62 (0.00)	11,204 (264)	95.2 (11.1)	12.7 (0.2)	0.65 (0.02)	1.62 (0.00)	3,751 (280)	54.0 (3.6)
	14.0 (0.1)	0.64 (0.01)	1.64 (0.00)	11,031 (799)	93.3 (8.9)	14.2 (0.2)	0.72 (0.01)	1.64 (0.00)	2,857 (869)	42.1 (15.3)
	19.6 (0.5)	0.65 (0.01)	1.75 (0.01)	9,766 (779)	85.0 (8.6)	20.5 (0.3)	0.66 (0.02)	1.77 (0.01)	2,860 (268)	49.3 (4.4)
	4.6 (0.1)	0.59 (0.04)	1.09 (0.00)	4,842 (149)	48.8 (6.2)	4.5 (0.1)	0.62 (0.02)	1.09 (0.00)	2,265 (310)	36.4 (3.4)
	7.2 (0.1)	0.61 (0.02)	1.11 (0.00)	4,679 (345)	48.7 (5.3)	8.1 (0.3)	0.64 (0.04)	1.12 (0.00)	1,555 (271)	24.4 (3.9)
ASS	13.1 (0.5)	0.61 (0.02)	1.19 (0.01)	3,784 (359)	40.9 (10.0)	11.1 (0.2)	0.58 (0.04)	1.16 (0.00)	1,706 (401)	28.6 (3.6)
	14.2 (0.2)	0.62 (0.02)	1.21 (0.00)	3,794 (283)	39.8 (2.6)	14.3 (0.2)	0.59 (0.02)	1.21 (0.00)	1,344 (280)	20.8 (4.3)
	19.7 (0.4)	0.63 (0.03)	1.33 (0.01)	2,938 (445)	32.0 (6.7)	19.9 (0.3)	0.64 (0.04)	1.34 (0.00)	1,201 (190)	18.8 (1.8)
	4.4 (0.1)	0.57 (0.01)	1.88 (0.00)	25,896 (2,514)	131.5 (5.1)	4.4 (0.1)	0.59 (0.01)	1.88 (0.00)	88,027 (8,562)	745 (35)
	7.3 (0.4)	0.58 (0.02)	1.95 (0.01)	25,435 (2,408)	126.5 (21.3)	8.9 (0.4)	0.54 (0.02)	1.98 (0.01)	72,108 (10,130)	603 (76)
ASF	12.8 (0.5)	0.58 (0.04)	2.07 (0.01)	18,927 (2,632)	99.3 (9.1)	11.5 (0.4)	0.55 (0.04)	2.04 (0.01)	65,151 (4,692)	530 (98)
	14.1 (0.4)	0.57 (0.01)	2.10 (0.01)	21,967 (1,636)	104.2 (12.7)	14.0 (0.2)	0.57 (0.02)	2.10 (0.00)	55,703 (8,606)	526 (46)
	21.2 (0.3)	0.59 (0.03)	2.25 (0.01)	16,138 (2,880)	83.8 (16.1)	19.9 (0.4)	0.55 (0.06)	2.22 (0.01)	45,941 (6,454)	379 (95)

[a] SPS-Southern pine OSB for sheathing; SPI-Southern pine OSB for I-beam; SPF-Southern pine OSB for floor underlayment; ASS-Aspen OSB for sheathing; ASF-Aspen OSB for floor underlayment.
[b] Value listed in parentheses is the standard deviation based on five specimens.
[c] Specific gravity was based on oven-dry weight and volume at 35% RH.
[d] Moment of inertia (I) is defined as $(b*h^3)/12$, where b is specimen width (7.62 cm), and h is specimen thickness (cm).
[e] Section modulus (S) is defined as $(2*I)/h$.

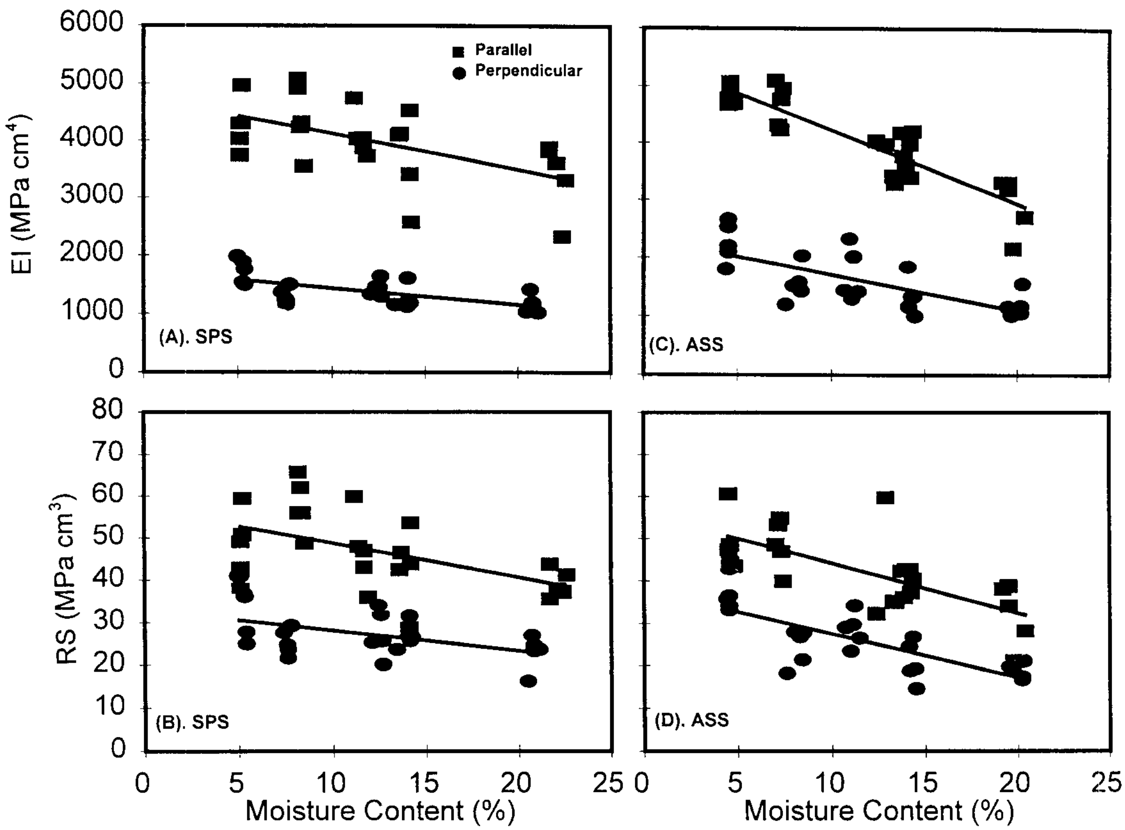

FIG. 1. Typical plots showing E·I (A: SPS; C: ASS) and R·S (B: SPS; D: ASS) as a function of MC. Lines show the linear fit of the data.

TABLE 2. *Summary of regression results on bending and breaking resistance, where E·I or R·S = A + B*MC.*

OSB	Parallel A	Parallel B	Parallel r^{2} [a]	Perpendicular A	Perpendicular B	Perpendicular r^2
			E·I			
SPS	4,754.141	−62.495	0.32	1,728.042	−28.367	0.38
SPI	4,261.256	−59.296	0.32	1,844.543	−36.589	0.47
SPF	13,871.008	−205.158	0.61	5,525.243	−144.126	0.63
ASS	5,527.998	−129.362	0.81	2,322.151	−61.033	0.47
ASF	28,815.591	−598.158	0.61	9,723.434	−271.947	0.75
			R·S			
SPS	56.926	−0.814	0.27	33.044	−0.476	0.23
SPI	66.742	−0.971	0.33	43.744	−0.677	0.23
SPF	92.121	−0.135	0.00	65.078	−0.842	0.26
ASS	55.807	−1.171	0.47	37.630	−1.020	0.57
ASF	144.352	−2.956	0.60	81.983	−2.247	0.70

[a] Coefficient of determination for the model between E·I or R·S and MC.

TABLE 3. *Summary of regression results on bending and breaking resistance, where E·I or R·S = C + D*MC + E*MC² + F*MC³.*

OSB	Parallel C	Parallel D	Parallel E	Parallel F	Parallel r^2 [a]	Perpendicular C	Perpendicular D	Perpendicular E	Perpendicular F	Perpendicular r^2
					E·I					
SPS	4,393.655	/ [b]	−2.207	/	0.32	4,087.879	−702.403	55.538	−1.371	0.56
SPI	3,937.929	/	−2.304	/	0.31	1,639.479	/	−1.355	/	0.47
SPF	12,780.242	/	−8.184	/	0.62	1,357.518	1,217.683	−126.291	3.437	0.74
ASS	4,889.386	/	−5.292	/	0.81	2,322.151	−61.033	/	/	0.47
ASF	28,815.591	−598.158	/	/	0.61	9,723.434	−271.947	/	/	0.75
					R·S					
SPS	−11.905	19.427	−1.705	0.042	0.46	83.209	−15.028	1.218	−0.031	0.40
SPI	61.629	/	−0.039	/	0.34	−38.178	22.568	−1.912	0.047	0.54
SPF	90.478	/	/	/	0.00	2.149	18.315	−1.677	0.044	0.40
ASS	50.131	/	−0.049	/	0.48	37.630	−1.020	/	/	0.57
ASF	128.365	/	−0.109	/	0.54	81.983	−2.247	/	/	0.70

[a] Coefficient of determination for the model.
[b] Terms that were not significant at the 0.05 level and were removed from the model by the backward selection procedure.

parent panels, were obtained directly from the manufacturers. Static bending specimens along the two principal directions were cut from each panel. Matched specimens were conditioned to equilibrium under each of five RH conditions: 35, 55, 75, 85, and 95% at 24°C. Their weight and size (i.e., length, width, and thickness) were measured. Bending tests were conducted on a Model 4260 INSTRON machine with computer-controlled data acquisition system. Each specimen was reweighed immediately after breaking. All specimens were then oven-dried for 24 hours at 104°C, and their oven-dry (OD) weight was determined. The MC of each specimen was calculated on the OD basis.

Test data on E, R, and specimen thickness at various MC levels were used to calculate moment of inertia (I), section modulus (S), E·I and R·S for each specimen in both material directions. E·I-MC and R·S-MC data were fitted to a linear model using SAS (1994):

$$Y = A + BMC \qquad [1]$$

where Y is the property (E·I, MPa cm⁴ or R·S, MPa cm³); A and B are regression constants. This linear model for E·I or R·S was used to be consistent with the earlier analysis on E or R (Wu and Suchsland 1997). To further process the data, E·I-MC and R·S-MC data were also fitted to a polynomial with linear, quadratic, and cubic terms in MC using a backward selection procedure (SAS 1994):

$$Y = C + DMC + EMC^2 + FMC^3 \qquad [2]$$

where Y is the property (E·I, MPa cm⁴ or R·S, MPa cm³); C, D, E, and F are regression constants. The backward selection procedure removed nonsignificant terms from the model. Thus the final model for each property included only terms that are significant at the 0.05 level.

RESULTS AND DISCUSSION

Table 1 summarizes MC, specific gravity, panel thickness, E·I and R·S in both parallel and perpendicular directions for the test panels. Typical plots of E·I and R·S as a function of MC in both directions are shown in Fig. 1. Table 2 shows the linear regression results for the E·I-MC and R·S-MC relationships. Table 3 lists the results of the polynomial regression model from the backward selection procedure.

Both E·I and R·S decreased with increase in the panel's MC (Table 1 and Fig. 1). There was a considerable amount of within-the-group variation in E·I and R·S at various MC levels (Fig. 1, for example). This variation was thought to be due to differences in both strength properties (E and R) and thickness swelling properties (panel thickness, I and S) among various specimens within a group. As a result, the coefficients of determination for the model between E·I or R·S and MC (Table 2) decreased significantly compared to those between E or R and MC reported in the earlier paper (Table 3 in Wu and Suchsland 1997). For SPF (southern pine OSB for floor), R·S values in the parallel direction varied little at various MC levels ($r^2 = 0.0039$).

Fitting of the data with Eq. (2) using the backward selection procedure led to some improvement in the coefficients of determination of the regression models, mainly for R·S (Table 3). In the parallel direction, models with only a quadratic MC term appeared to provide the best fit for most of the panels. In the perpendicular direction, the data (both E·I and R·S) from three southern pine products were best fitted with polynomials including all linear, quadratic, and cubic terms. The data for two aspen products were best fitted with linear models.

For an MC change from 4 to 24%, Eq. (1) and Table 2 predicted an average E·I loss, defined as $[(E{\cdot}I)_{4\%MC} - (E{\cdot}I)_{24\%MC}]/[(E{\cdot}I)_{4\%MC}]$ in percent, of 37% in the parallel direction and 51% in the perpendicular direction; and to an average R·S loss of 31% in the parallel direction and 43% in the perpendicular direction. These data compared with an average E loss of 72% in the parallel direction and 83% in the perpendicular direction; and to an average R loss of 58% in the parallel direction and 67% in the perpendicular direction reported in the earlier paper. The smaller amount of reduction in E·I and R·S was due to increase in panel thickness as a result of thickness swelling. Among the five products, two aspen products had the larger losses in both E·I and R·S along both material directions than the southern pine products.

CONCLUSIONS

Bending resistance, E·I, and breaking resistance, R·S, of commercial OSB decreased with increase in the panel's MC. However, the extent of moisture-related reduction in both E·I and R·S was significantly smaller than that of modulus of elasticity, E, and modulus of rupture, R. This smaller amount of reduction in E·I and R·S was attributed to increases in panel thickness at higher MC levels. The data on bending and breaking resistance in commercial OSB should aid in estimating current strength and safety margins in field use of OSB.

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