LINEAR EXPANSION AND ITS RELATIONSHIP TO MOISTURE CONTENT CHANGE FOR COMMERCIAL ORIENTED STRANDBOARDS

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ABSTRACT

Linear expansion (LE) was measured along two principle directions for five types of commercial oriented standboard (OSB). The measurements were made over four wetting steps from 35 percent to 95 percent relative humidity (RH) at 24°C. LE along both parallel and perpendicular directions of all OSBs occurred at a greater rate for moisture content (MC) change in the lower MC region. Statistical comparisons of the LE data between parallel and perpendicular directions for a given OSB and among various OSBs were performed. Regression equations expressing LE as a function of MC change were established for various products.

Linear expansion (LE), occurring in response to increased moisture content (MC) of the material, is one of the important material properties for structural oriented strandboard (OSB). This is because the in-plane expansion or movement can cause high internal stresses when it is totally or partially restrained by external fastening such as nails during service (2,6). These stresses may be large enough to cause buckled panels, pushed-out nails, and separation of the panel from the structure. Detailed knowledge of LE and its relationship to MC change can provide valuable insights into the performance of OSB.

The fundamental relationship between shrinkage or swelling and MC change in solid wood has been extensively studied (4,7). It has been shown that, for example, transverse shrinkage or swelling has a linear relationship to MC change over a considerable MC range below the fiber saturation point. However, a consistent relation between the LE of OSB and changes in MC is still lacking. This is especially true for commercial OSBs, which exhibit wide variation in both flake size and flake alignment. Pu et al. (3) reported results of LE measurement for six types of commercial OSBs under ovendry (OD) to vacuum-pressure- soaked (VPS) conditions. Zylkowski (8,9) measured LE and thickness swelling of several structural-use panels including plywood, waferboard, and OSB. In particular, he defined the relative LE as the percentage of total dimensional change from OD to VPS condition for a given humidity exposure. He showed that the relative LE was nearly the same for all materials and the major part of the expansion occurred at low MC levels. More recently, Lang and Loferski (2) reported measurements on both free LE and restrained LE for plywood and OSB after a 4-day exposure at 95 percent RH.

The LE and stiffness of OSB are largely determined by the construction of the panel. Manufacturers can manipulate construction variables such as the weight ratio between face and core to achieve the desired stiffness and LE for different applications. For a given board construction, however, LE is controlled by the longitudinal swelling of wood (1) which is usually small (typically less than 0.5% compared with 6% to 12% in transverse directions). Because of the small magnitude of LE for OSB, more accurate measurements are necessary than when studying transverse shrinkage or swelling of wood. Suchsland (5) developed an optical device and demonstrated subsequently that the device could be used to accurately measure such a small dimensional change for wood-based products (5,6).

In this study, LEs of five types of commercial OSBs were measured. The objectives of the study were to compare LE among OSBs for various applications and to examine the relationship between LE and changes in MC for various products.

MATERIAL AND METHODS

Five different commercial OSBs were selected for the study (**Table 1**). These typify the two most widely used wood species (aspen and southern pine) and three major applications (sheathing, floor underlayment, and I-beam web) for OSB

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TABLE 1. — Panel properties for various OSBs used in the study.[a]

Type of OSB	Thickness[b]	Specific gravity[c]
	(mm)	
Southern pine		
Sheathing (SPS)	10.9	0.66
I-beam web (SPI)	10.2	0.73
Floor underlayment (SPF)	15.2	0.66
Aspen		
Sheathing (ASS)	10.9	0.61
Floor underlayment (ASF)	18.8	0.58

[a] All the panels were made with phenol-formaldehyde adhesive.
[b] Thickness was at 35 percent relative humidity and 24°C. The thickness ratio of face-core-face was about 1:2:1 for all the products.
[c] Specific gravity was based on ovendry weight and volume at 35 percent relative humidity.

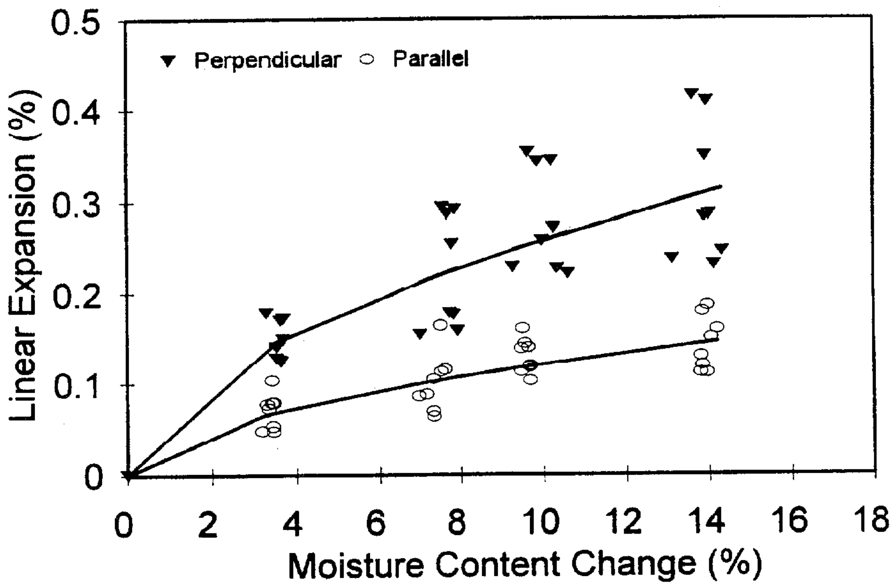

Figure 1. — A typical plot showing linear expansion as a function of change in moisture content. Data shown are for SPS with lines representing a power-law form fit. The average initial moisture content was 7.4 percent.

products. Among these, three southern pine OSBs were manufactured in one mill, and two aspen OSBs were made in another mill. Two panels measuring 122 by 122 cm of varying thicknesses of each type of OSB, cut from two separate 122- by 244-cm parent panels were obtained directly from the manufacturer in a concurrent study. Test samples were prepared from these 10 panels.

Eight linear expansion specimens measuring 25.4 by 304.8 mm of varying thicknesses were cut along each of the two principle directions (parallel and perpendicular to the major flake alignment direction in the face layer) from each OSB type, totaling 80 specimens. Two holes (1.1-mm diameter) 254 mm apart were drilled along the long dimension of each specimen. A small rivet (1.0-mm diameter), dipped in epoxy glue, was plugged into each of the two holes. After the glue was set, one reference cross was carefully cut on the tip of each rivet using a sharp razor blaze. All specimens were placed in a climate-controlled chamber and went through a series of conditioning steps. The temperature inside the test chamber was 24°C.

Measurements of weight, specimen thickness, and reference dimension between the two rivets were performed after an 8-week conditioning at each of the five levels of relative humidity (RH): 35, 55, 75, 85, and 95 percent. The dimensional change was measured with an optical comparator (5). At the end of the last RH level, all specimens were ovendried and weighted. LE was calculated as:

TABLE 2. — Mean value and standard deviation of moisture content (MC) change and linear expansion (LE) for various OSBs.

		RH:35% to 55%		RH:35% to 75%		RH:35% to 85%		RH:35% to 95%	
OSB	Initial MC	DMC[b]	LE	DMC	LE	DMC	LE	DMC	LE
	(%)								
Parallel									
SPS	7.4 (0.4)[a]	3.4 (0.1)	0.07 (0.02)	7.4 (0.2)	0.10 (0.03)	9.6 (0.1)	0.13 (0.02)	13.9 (0.1)	0.14 (0.03)
SPI	7.0 (0.1)	2.7 (0.2)	0.10 (0.01)	6.1 (0.3)	0.15 (0.02)	10.1 (0.1)	0.17 (0.02)	12.6 (0.2)	0.17 (0.03)
SPF	6.1 (0.1)	3.0 (0.2)	0.08 (0.02)	6.7 (0.2)	0.11 (0.03)	10.4 (0.2)	0.14 (0.03)	12.9 (0.6)	0.16 (0.03)
ASS	4.8 (0.1)	4.1 (0.1)	0.09 (0.02)	8.2 (0.2)	0.13 (0.02)	11.0 (0.1)	0.17 (0.02)	15.3 (0.1)	0.19 (0.02)
ASF	4.8 (0.1)	2.2 (0.2)	0.04 (0.01)	6.5 (0.1)	0.09 (0.01)	12.6 (0.2)	0.14 (0.02)	15.4 (0.1)	0.16 (0.02)
Perpendicular									
SPS	7.5 (0.4)	3.6 (0.1)	0.15 (0.02)	7.7 (0.3)	0.22 (0.06)	10.0 (0.4)	0.28 (0.05)	13.9 (0.3)	0.31 (0.07)
SPI	6.9 (0.1)	2.1 (0.1)	0.12 (0.01)	5.5 (0.1)	0.21 (0.04)	10.2 (0.1)	0.29 (0.04)	12.5 (0.1)	0.31 (0.05)
SPF	6.3 (0.1)	2.0 (0.3)	0.11 (0.01)	5.8 (0.2)	0.19 (0.03)	10.9 (0.1)	0.32 (0.05)	13.5 (0.1)	0.35 (0.04)
ASS	5.0 (0.1)	4.5 (0.1)	0.10 (0.02)	8.9 (0.1)	0.12 (0.03)	11.0 (0.1)	0.19 (0.03)	16.5 (0.1)	0.21 (0.03)
ASF	4.9 (0.1)	3.6 (0.5)	0.09 (0.02)	7.6 (0.7)	0.17 (0.04)	11.8 (0.5)	0.30 (0.05)	16.1 (0.4)	0.36 (0.06)

[a] Values in parentheses are standard deviations based on eight specimens.
[b] DMC was defined as the difference between the MC at a given relative humidity and the initial MC.
[c] Average thickness swelling from 35 percent to 95 percent relative humidity for SPS, SPI, SPF, ASS, and ASF was, respectively, 21.0, 15.5, 16.0, 25.5, and 19.5 percent based on the thickness at 35 percent relative humidity.

$$LE = \left[\frac{L_I - L_O}{L_O}\right] \times 100\% \quad [1]$$

where:

LE = linear expansion in percent (mm/mm)

L_I = reference dimension at a given RH level (mm)

L_O = reference dimension at the reference RH level (mm). The reference RH level was 35 percent

The MC for each specimen was calculated on the OD basis. The change in MC (DMC (%)) was defined as the difference between the MC at a given RH and the initial MC:

$$DMC = MC_I - MC_O \quad [2]$$

where:

MC_I = MC at a given RH level (%)

MC_O = MC at the reference RH level (%).

The LE coefficient (LEC), percent/percent MC, was calculated as a ratio of LE and MC change (i.e., LE/DMC). Based on results from this study and those made by Zylkowski (8,9), a power-law form equation was used to fit the LE and DMC data:

$$LE = A\ DMC^B \quad [3]$$

where:

A and B = regression constants

In fitting the data, a natural logarithm (Ln) transformation of both LE and DMC data was first performed. A linear regression analysis with Ln(LE) as the dependent variable and Ln(DMC) as the independent variable was then made.

Results and Discussion

Both panel thickness and specific gravity (SG) varied among the five types of OSB used in the study (**Table 1**). The higher SG for SPI increased its strength properties for application as the web material in an I-beam. The mean value and standard deviation of MC change and LE from the RH steps are summarized in **Table 2** for all five OSBs. **Figure 1** shows a typical plot of LE as a function of MC change in parallel and perpendicular directions of a given OSB. Plots showing the combined data of all OSBs are shown in **Figure 2a** for the perpendicular direction and **Figure 2b** for the parallel direction.

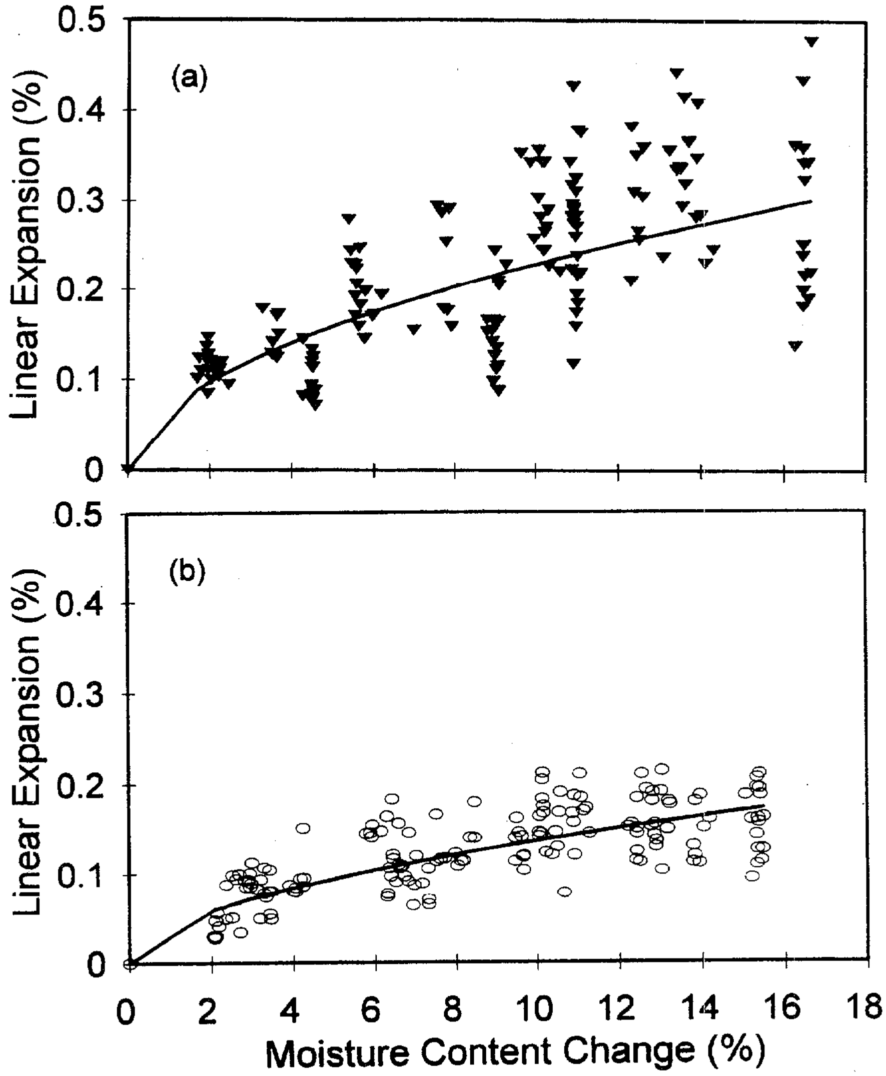

Figure 2. — Linear expansion as a function of change in moisture content from the combined data for all OSBs used in the study. (a) = perpendicular direction; (b) = parallel direction. The lines represent the fit of data. The average initial moisture content for all OSBs was 6.1 percent.

Difference in LE between Parallel and Perpendicular Directions

LE in the perpendicular direction for SPI, SPS, SPF, and ASF was clearly larger than in the parallel direction (**Table 2** and **Fig. 1**). For ASS, however, there seemed to be no difference between these two directions (**Table 2**). LE data in the perpendicular direction had a considerably larger variation than in the parallel direction, especially at higher RH levels (**Figs. 1** and **2**).

Beacuse the absolute value of LE depends on change in MC, rather than the MC itself, a statistical comparison was made to see if there were differences in LECs between the two directions. LE and MC data from the combined wetting step (35% to 95% RH) were used for these purposes. The results of a two-sample comparison procedure showed that except for ASS, LECs in the perpendicular direction were significantly larger than those in parallel direction ($p < 0.05$). Thus, most commercial OSBs present different swelling or shrinkage potential along two principle directions. Consideration should be given to account for this difference in using commercial OSB. The apparently insignificant difference for LE between parallel and perpen-

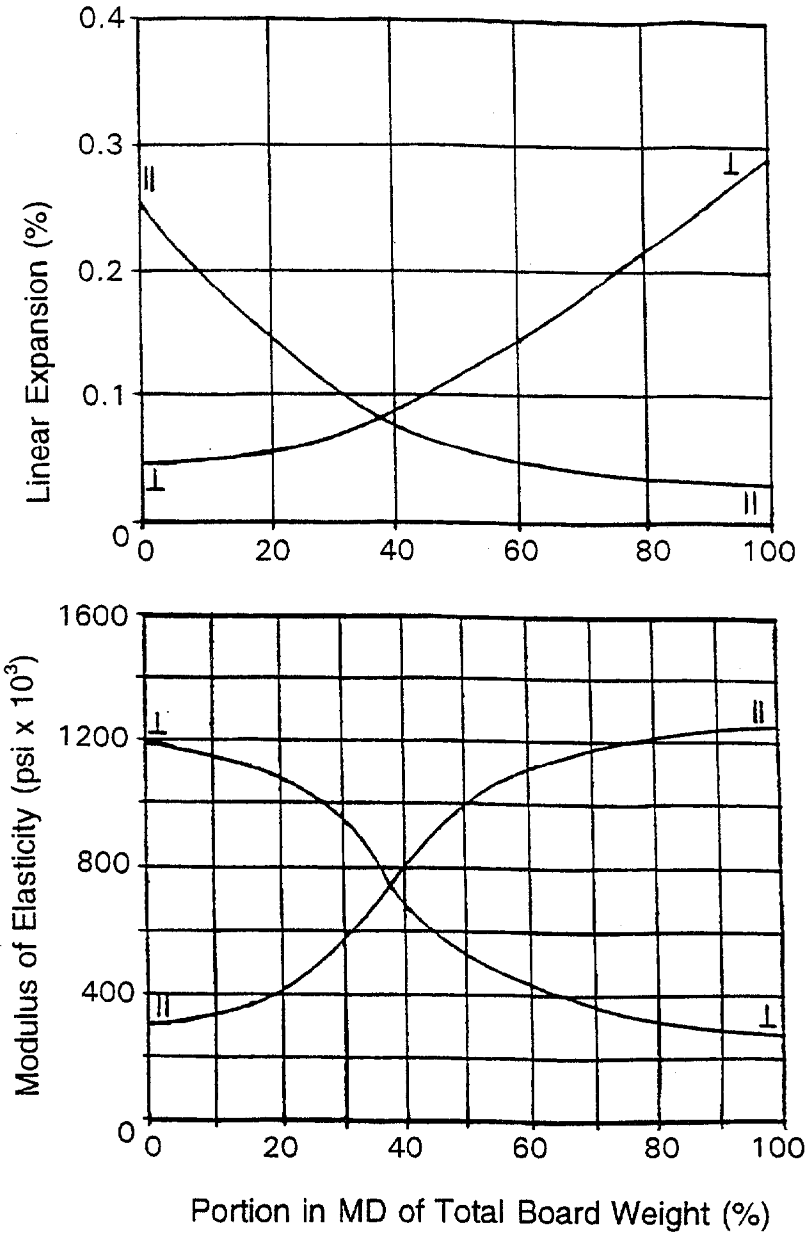

Figure 3. — Linear expansion (top) and modulus of elasticity (bottom) as a function of layer weight ratio adapted from Siempelkamp Corp. promotion literature. Linear expansion was measured from 50 to 90 percent RH at 20°C. | | (parallel) and ⊥ (perpendicular) are with respect to the machine direction (MD). (1 psi = 6894 Pa.)

dicular direction for ASS may be due to the particular manufacturing process for the panel.

Difference in LE among various OSBs

LE values from the combined wetting step (35% to 95% RH) varied among five OSBs due to differences in MC changes. However, in the parallel direction, LECs were not significantly different for all five OSBs based on a Duncan's multiple comparison procedure at the 95 percent level of confidence. In the perpendicular direction, LECs for SPI, SPF, ASF, and SPS were also not significantly different, while values for ASS were smaller. This result suggests that broad behaviors of LE were similar for all OSBs used in the study despite differences in wood species, panel thickness, and other manufacturing variables among various products.

It should be pointed out that manufacturers can purposely manipulate the magnitude of LE between the two principle directions of a given OSB and among OSBs for different applications by changing the construction of the panel (**Fig. 3**). The results from this study indicate that the manufacturers intentionally aimed at these particular LE balances or that these LE balances were consequences of board design aimed at particular stiffness balances.

Relationship between LE and MC change

Linear expansion followed a power-law form relation with MC change (**Figs. 1** and **2** and **Table 3**). A given MC change in the lower MC range produced more LE than it did in the higher MC range. Therefore, the linear expansion coefficient decreased as MC increased. Similar observations were also made by Zylkowski (8, 9).

The larger rate of LE development in the lower MC range for OSB followed the longitudinal swelling behavior of

TABLE 3. — Regression coefficients for the relationship between linear expansion (LE) and moisture content (MC) change of various OSBs.[a]

	Parallel			Perpendicular		
OSB	A	B	r^{2b}	A	B	r^{2b}
SPS	0.0349	0.5421	0.60	0.0743	0.5412	0.62
SPI	0.0679	0.3803	0.68	0.0861	0.5092	0.83
SPF	0.0457	0.4767	0.49	0.0675	0.6252	0.90
ASS	0.0409	0.5649	0.76	0.0422	0.5552	0.54
ASF	0.0243	0.6514	0.85	0.0290	0.9109	0.87
ALL[c]	0.0398	0.5349	0.58	0.0668	0.5354	0.50

[a] $LE = A (DMC)^B$, $DMC = MC_1 - MCO$. The initial MC (MC_O) for SPS, SPI, SPF, ASS, ASF, and ALL were, respectively, 7.4, 7.0, 6.1, 4.8, and 6.1 percent.
[b] Correlation coefficient between LE and MC change.
[c] ALL = combined data for all OSBs used in the study.

solid wood. Sadoh and Christensen (4) showed that longitudinal swelling or shrinkage of thin wood sections was very small for MC change above the 12 percent level and increased at a larger rate with MC change below 12 percent. This result provided further evidence that longitudinal swelling of wood controls the LE of OSB, at least in the lower MC range.

The continuous increase of LE for MC change well above 12 percent MC, especially in the perpendicular direction, was thought to be mainly due to the effect of transverse swelling of wood. Commercial OSBs were made with a three-layer construction, in which the flakes were running at a 90 degree angle between face and core layers. Also, wood flakes in either face or core layer were not perfectly aligned with either parallel or perpendicular direction of the panel. Thus, both longitudinal and transverse swelling of wood would contribute to panel's expansion during moisture adsorption. In the lower MC range, longitudinal swelling of wood dominated the panel's LE due to its relatively larger rate of development and high wood strength along the longitudinal direction. At higher MC levels, however, the rate of longitudinal wood swelling decreased greatly (4) and contribution from the transverse swelling became more significant. It should be pointed out that transverse swelling only occurred in a limited sense because of the restriction offered by high wood strength along the longitudinal direction. Because longitudinal swelling of wood cannot be changed, attempts to reduce the LE of OSB should be made to limit contributions from the transverse direction. Improved flake alignment and better selection of the design variables such as face and core weight ratio, resin content, and vertical density gradient will help achieve these goals.

The power-law form equation appears to fit the LE-MC data (**Table 3**). The combined data showed considerable variations at a given MC level, which reduced the correlation coefficient between the two variables. The fact that OSB expands more for MC change in the lower MC range suggests that a conditioning process to bring the MC of the panel to a higher MC, for example 12 percent, before use would help stabilize the in-plane movement of the product. Also, a constant LEC cannot be used to predict LE over the whole MC range.

SUMMARY AND CONCLUSIONS

LE in a structural OSB occurred as a result of its MC increase within the hygroscopic range. Despite differences in wood species and manufacturing variables, the broad features of LE were similar among various OSB products used in the study.

At lower MC levels, LE for all OSBs occurred at a greater rate and followed the longitudinal swelling behavior of solid wood. At higher MC levels, LE developed at a reduced rate and was mainly due to the effect of transverse swelling of wood. Improvement of flake alignment and better selection of design variables of the panel would reduce this transverse effect and the overall LE of the panel.

The study has generated a set of regression equations describing LE as a function of MC change that can be used to estimate LE for various OSB products. A further study investigating the effect of various manufacturing variables on LE of OSB is underway.

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