Characterizing Variability of Commercial Oriented Strandboard: Bending Properties

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Abstract

To characterize the variation in bending modulus of elasticity (MOE) and modulus of rupture (MOR), two commercial oriented strandboard (OSB) products were selected. Master panels from multiopening, large hot presses were cut into standard panels of 1,220 by 2,440 mm, and then a total of 3,420 bending specimens were prepared in a continuous order and tested. The variations in bending properties were compared in terms of coefficient of variation (CV) and property differences both between and within master panels. The differences were evaluated by conducting analysis of variance and least significant difference tests. The correlation between MOE and MOR was also investigated. The results showed that the thicker OSB had less variation in bending properties than the thinner product. The variation of MOE (CV = 12% to 16%) was lower than that of MOR (CV = 20% to 22%). Although no significant differences were found in bending MOE and MOR between master panels, significant variations were noted in MOE and MOR within master panels. The differences in MOE and MOR between standard panels varied from 4 to 11 percent, and those along and across the forming line could vary from 8 to 17 percent and from 33 to 59 percent, respectively. The results suggest that product uniformity needs to be improved both along and across the forming line to lower production cost and improve product performance. The relationship between MOE and MOR was linear, with R^2 around 0.7.

An oriented strandboard (OSB) panel is manufactured by depositing resinated wood strands to form a mat. The mat is then consolidated in a hot press under pressure and heat. Naturally, the discontinuous strands in a mat are not distributed and densified in a uniform manner, resulting in variability that can be characterized by horizontal and vertical density distributions. This variability in structure results from the variability in raw materials (wood species, strand size, and geometry) and the forming as well as pressing processes. Consequently, the variability in structure yields the variability in properties within and between final products.

Several publications have reported property variation of commercial wood-based composites, but most of these have considered particleboard and medium-density fiberboard (MDF; Biblis 1989a; Winstorfer and Moschler 1989; Cassens et al. 1994; Xu and Suchsland 1998, 1999; Semple et al. 2005a, 2005b). Generally speaking, the horizontal density variation of nonveneer wood composites increases with the dimensions of the wood elements (Dai and Steiner 1994, Kruse et al. 2000). Hence, OSB has been recognized as a material with relatively higher variability in structure and properties because of the much larger size of strands compared with MDF and particleboard. As a structural material, OSB should have high reliability in its performance. From the viewpoint of the end-application, such as construction sheathing, an OSB product should be acceptable if it meets the performance criteria specified in the performance-based standards, such as CSA O325 (Canadian Standards Association [CSA] 2007) or PS2 (National Institute of Standards and Technology 2004), regardless of product variability. However, for a producer, decrease in property variation means an opportunity for lowering panel density and, thus, production cost. On the other hand, OSB manufacturers may not fully understand or offer little information on their product variability. Only a number of limited publications are related to this topic. Biblis (1989b) tested properties of nine 1,220 by 2,400 by 11.1-mm OSB panels sampled from three southern pine mills, and significant differences in properties between boards were found. A comprehensive testing program was conducted by

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Forintek Canada Corp. (currently FPInnovations–Wood Products Division) to evaluate the structural properties of OSB panels produced by all the mills affiliated with the Structural Board Association. The results showed significant differences in the bending, shear, and axial properties of OSB panels of the same grade produced between different mills and within a product (Karacabeyli et al. 1996).

Despite continuous advancements in OSB production technology, such as the introduction of longer strands and the adoption of new equipment like larger, multiopening hot presses, published data characterizing the property variation of current commercial OSB products seem to be lacking. Furthermore, little information is available about property variation within a master panel from a press opening and between master panels from different press openings from the same press run. Previous publications (Biblis 1989b, Karacabeyli et al. 1996) provided information on variation in bending properties of OSB products based only on a limited number of specimens sampled from the panels. Hence, a more thorough and comprehensive investigation on the continuous distribution of bending properties within a panel is needed.

This article focuses on the variation in bending properties of OSB: modulus of rupture (MOR) and modulus of elasticity (MOE). The specific objectives are

- to examine the spatial distribution of bending properties within a press opening;
- to create a database to characterize the variability of bending properties for two typical commercial OSB products (thick and thin panels);
- to analyze statistically the variations in bending properties both within and between press openings for two OSB products; and
- to determine the correlation between the MOR and MOE of two commercial OSB products.

Materials and Methods

Materials

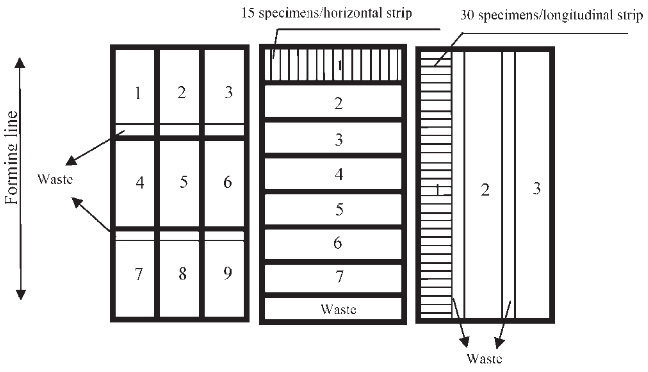
Two commercial OSB products were obtained. Product A was provided by Mill A, which has a forming line 12 feet (4 m) in width and a multiopening press. Product B was from Mill B, which has a forming line 8 feet (2.7 m) in width and also has a multiopening press. For Product A, a *master panel* (i.e., the full-size panel from a press opening) was measured as 7.32 m in length by 3.66 m in width by 11.1 mm in thickness. The product was made from aspen strands and bonded with phenol-formaldehyde (PF) resin. The dimension of a master panel for Product B was 4.88 m in length by 2.44 m in width by 18.3 mm in thickness. This product mainly consisted of aspen and was bonded with PF resin in the face layers and polymeric diphenylmethane diisocyanate in the core layers.

Three master panels of each product were sampled from a press load. All the master panels were cut into *standard panels* measuring 1,220 by 2,440 mm (Figs. 1a and 2a). In total, 27 standard OSB panels from Mill A and 12 panels from Mill B were used.

Specimens preparation and evaluation

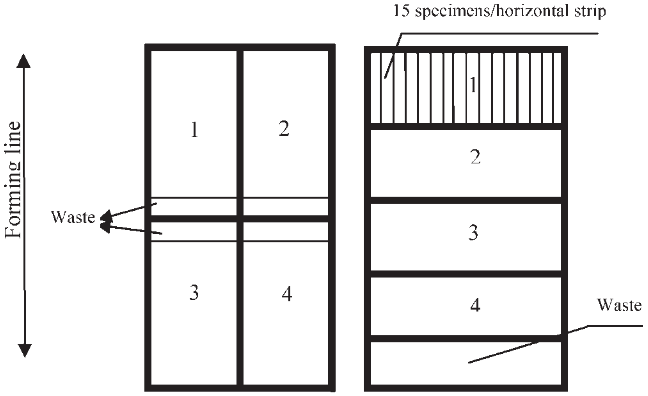
Cutting patterns.—To investigate the variation in bending properties both between and within the master panel (i.e., press opening), different cutting patterns were designed for the two products according to their thickness and size (Figs. 1 and 2). By adopting these patterns, the within-master-panel variation was investigated from three different aspects: variation between standard panels as well as variation between specimen rows and columns (i.e., along and across the forming line). This design was chosen for two reasons. First, OSB products are traded and mostly used in the form of a standard panel. It is important to reduce variations between and within those panels both from the same pressing opening and from different openings of a press load. Second, it is also desirable to examine the continuous distribution of bending properties along and across the forming line.

The width and length of bending specimens were determined based on panel thickness according to CSA O437.1 (CSA 1993b). All the bending specimens were cut starting from the outside edge of the standard size panels



(a) (b) (c)

Figure 1.—Cutting pattern of Product A: (a) master panel cut into nine standard panels; panels marked 1, 2, 3, 7, 8, and 9 were cut into specimens for the parallel bending test, while panels labeled 4, 5, and 6 were for the perpendicular bending test; (b) cutting pattern for preparing parallel bending specimens from a standard panel; and (c) cutting pattern for preparing perpendicular bending test specimens from a standard panel.



(a) (b)

Figure 2.—Cutting pattern of Product B: (a) master panel cut into four standard panels and (b) cutting pattern for preparing parallel bending specimens from a standard panel.

and moving inward to include the edge effects (Figs. 1 and 2).

Specimens for Product A.—Bending specimens parallel and perpendicular to the panel length were cut separately from the standard panels. Three standard panels marked 4, 5, and 6, which located in the center of a master panel, were cut into the bending specimens in perpendicular direction while the other six panels (marked 1, 2, 3, 7, 8, and 9) were prepared for specimens in the parallel direction (Fig. 1a). Altogether, 9 and 18 standard panels were used for testing bending properties perpendicular to the panel length and parallel to the panel length, respectively.

For parallel bending tests, each standard panel was cut into seven 317 by 1,220-mm horizontal strips (referred to as specimen rows), and 15 specimens measuring 75 by 317 mm were prepared from each strip (Fig. 1b). Note that Figure 1b only gives the cutting pattern for standard panels 1, 2 and 3. A mirror image of this pattern was adopted for panels 7, 8, and 9. Therefore, the total number of parallel bending specimens from Product A was 1,890. Resulting from this cutting pattern were 14 specimen rows distributed along the forming line and 45 specimen columns distributed across the forming line in each master panel of Product A. Consequently, the differences in bending properties along and across the forming line were determined by comparing the differences between specimen rows and columns.

To prepare specimens for the perpendicular bending test, three longitudinal strips (referred to as specimen columns) measuring 317 by 2,440 mm were cut from each standard panel, and 30 specimens were cut from each longitudinal strip (Fig. 1c). The total number of perpendicular bending specimens from Product A was 810. In this case, 30 specimen rows and nine specimen columns were tested across the forming line in a master panel.

Specimens for Product B.—Because of the smaller dimensions of the master panel, only parallel bending specimens were prepared for Product B. Four horizontal strips (referred to as specimen rows) along the forming line were cut from each standard panel (Fig. 2b). Then, 15 specimens measuring 75 by 488 mm were cut from each strip, resulting in a total of 60 specimens for each standard panel. Again, the cutting pattern for panels 1 and 2 was the mirror image of that for panels 3 and 4. Therefore, in a master panel, eight specimen rows were along the forming line, and 30 specimen columns were across the forming line. The total number of bending specimens was 720.

Evaluation of static bending properties.—CSA O437.0 (CSA 1993a) and CSA O437.1 standards (CSA 1993b) were followed in determining the specimen dimension, test method, and minimum required values for static bending properties. The mass and dimensions (i.e., thickness, width, and length) of each specimen were taken to calculate the actual density of each specimen. A center-loading bending test was conducted for all the bending specimens according to CSA O437.1 (CSA 1993b).

Data analysis

The minimum, maximum, mean, standard deviation (SD), and coefficient of variation (CV) of bending properties for each product were calculated. Statistical analysis was further carried out using SAS software (SAS Institute Inc. 2004). Analysis of variance (ANOVA) was used to check for significant differences in bending properties between and within press openings (i.e., master panels). Least significant difference (LSD), a multiple range test involving a *t* test, was used to make pairwise comparison of the means of bending properties. The correlations between MOE and MOR of two products were also determined.

Results and Discussion

Bending properties and variation

The minimum, maximum, mean, SD, and CV values of bending properties for each product are summarized in Table 1, along with the requirements for OSB Grades O-1 and O-2 according to CSA O437.0 (CSA 1993a). Product A met the requirements for O-1 but not for O-2, while Product B failed to quality for either grade. Table 1 shows that the CV values of MOE (12% to 16%) were lower than those of MOR (20% to 22%), i.e., MOR had higher variation than MOE for both products. As expected, the thinner OSB (Product A) had a slightly higher variation in the parallel bending properties ($MOE_{//}$ and $MOR_{//}$) than the thicker OSB (Product B). The CV values of the $MOE_{//}$ and $MOR_{//}$ of Product B (18.3 mm thick) were about 2 percent lower than those of Product A (11.1 mm thick). Generally speaking, thicker panels have a more uniform structure than thinner panels, because thicker panels have more strands in panel and, therefore, less variation in panel properties. As the two products are from different mills, the differences in variation between the two products evaluated could result, in part, from the processing parameters, equipment type and conditions, strand geometry, and raw materials used in the two mills.

A comparison of the CV values of bending properties (MOE and MOR) for commercial MDF, particleboard, embossed hardboard, and OSB products is shown in Table 2. The CV values of bending properties for the two OSB products in this study fell in the same range as previously observed (Karacabeyli et al. 1996, Biblis 1989b) except for $MOR_{//}$. The CV values of $MOR_{//}$ of the current products were 3 to 9 percent higher than the previous results. In general, higher variability in properties could result from the forming process (because of poor former performance). Also, the use of large strands is prone to resulting in increased variation of horizontal density distribution (Kruse et al., 2000) and, thus, higher variation in panel properties. Particleboard and MDF are recognized as products with lower variability compared with OSB; therefore, less variation in bending properties for those two products are expected. Although the CV values of bending properties for some MDF panels can be up to 14 or even 18 percent, depending on the sources of manufacturing (Winistorfer and Moschler 1989), OSB does show a higher variation in general compared with MDF and particleboard.

Variation between master panels (press openings)

The two-way ANOVA results show no significant differences in bending properties between master panels for both OSB products, with the exception of the perpendicular MOR ($MOR_{\perp}$) for Product A (Table 3). This suggests that the variation between master panels from the same press load, which is caused mainly by differences in the hot-press conditions among different sets of platens, was very small for the two products.

Table 3 also shows significant interaction effects from master panel and standard panel on the bending properties,

Table 1.—Overall bending properties of two OSB products.[a]

Statistic or standard	A (11.1 mm thick) $\text{MOE}_{//}$ (GPa)	A (11.1 mm thick) $\text{MOR}_{//}$ (MPa)	A (11.1 mm thick) $\text{MOE}_{\perp}$ (GPa)	A (11.1 mm thick) $\text{MOR}_{\perp}$ (MPa)	B (18.3 mm thick) $\text{MOE}_{//}$ (GPa)	B (18.3 mm thick) $\text{MOR}_{//}$ (MPa)
Mean (minimum, maximum)	4.98 (2.79, 7.42)	27.3 (10.9, 49.5)	1.95 (1.13, 3.70)	14.4 (6.5, 29.6)	4.35 (2.93, 6.39)	21.4 (9.8, 38.0)
SD	0.71	5.9	0.31	3.1	0.52	4.2
CV (%)	14	22	16	21	12	20
CSA requirements						
O-1	4.5	23.4	1.3	9.6	4.5	23.4
O-2	5.5	29.0	1.5	12.4	5.5	29.0

[a] Data were calculated based on all individual specimens from a product.

Table 2.—Comparison of variation in bending properties of different commercial panel products.

Product	Coefficient of variation (%) $\text{MOE}_{//}$	$\text{MOE}_{\perp}$	$\text{MOR}_{//}$	$\text{MOR}_{\perp}$	Source
OSB	12, 14	16	22, 20	21	Present study
OSB	11–16	6–22	13–19	7–30	Biblis (1989b)
OSB	4–17	4–15		—	Karacabeyli et al. (1996)
M2 particleboard	7–16	3–12	5–17	4–14	Semple et al. (2005a)
Particleboard	3, 7		5, 6		Xu and Suchsland (1998)
MDF	7–14		6–18		Winistorfer and Moschler (1989)
Embossed hardboard	5–18	9–19	8–16	4–25	Biblis (1989a)

Table 3.—Summary of ANOVA tests.[a]

Method	Factor	Product A $\text{MOE}_{//}$	Product A $\text{MOR}_{//}$	Product A $\text{MOE}_{\perp}$	Product A $\text{MOR}_{\perp}$	Product B $\text{MOE}_{//}$	Product B $\text{MOR}_{//}$
Two-way ANOVA with interaction	Master panel	0.305 NS	0.08 NS	0.393 NS	0.0101 S	0.093 NS	0.385 NS
	Standard panel	0.026 S	0.022 S	<0.001 S	<0.001 S	<0.001 S	<0.001 S
	Interaction	<0.001 S	0.169 NS	<0.001 S	0.0001 S	<0.001 S	0.005 S
Three-way ANOVA without interaction	Master panel	0.282 NS	0.066 NS	0.386 NS	0.009 S	0.027 S	0.243 NS
	Specimen column	<0.001 S	<0.001 S	<0.001 S	<0.001 S	<0.001 S	<0.001 S
	Specimen row	<0.001 S	<0.001 S	0.720 NS	0.252 NS	<0.001 S	<0.001 S

[a] Values are *P* values. NS = not significant at the 0.05 level; S = significant at the 0.05 level.

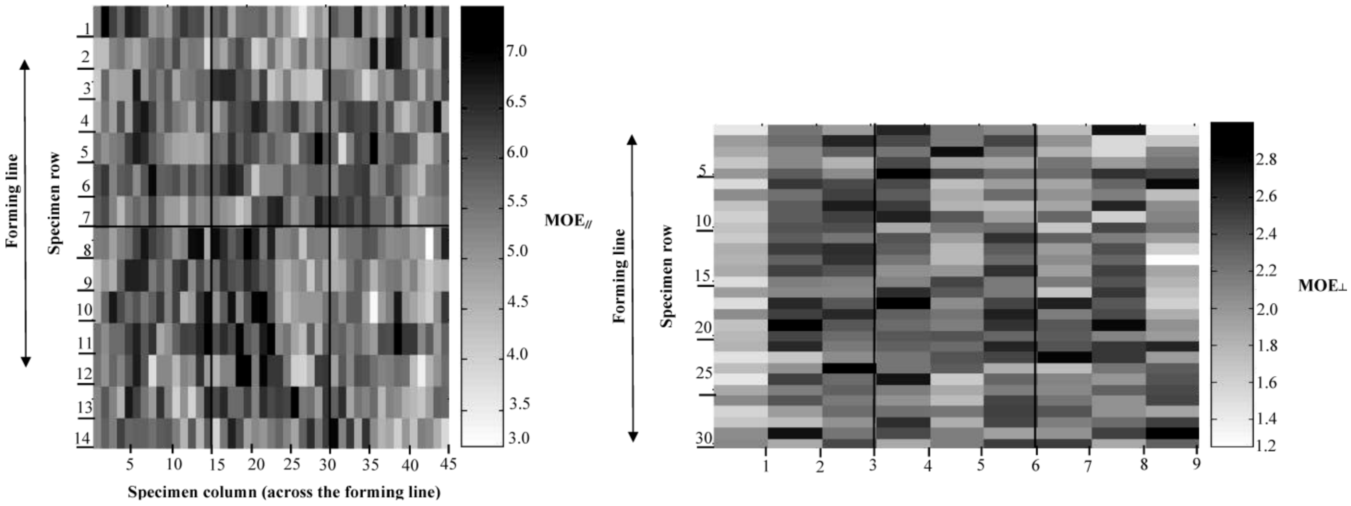
with the exception of $\text{MOR}_{//}$ for Product A. This significant effect basically means that one of the master panels has more within-master-panel variation in bending properties than the others. The variation could result from that of the press platens (e.g., within-platen temperature variation).

Variation within master panels (press openings)

Unpredictable variability in properties requires higher average board density and, thus, heavier products and more raw materials consumption. It also results in decreased product reliability. For products manufactured with a larger, multiopening hot press, within-master-panel variation or difference in properties needs to be kept as low as possible in terms of variation between standard size panels, along and across the forming line. MOE distributions within master panels of the two products are exemplified in Figure 3. Areas of both relatively high and low bending properties were observed, which means that the distributions of MOE are not uniform within a master panel. The areas of lower bending properties are prone to failure in a normal application; therefore, a higher average board density or resin level is required for increasing the total bending performance of the product.

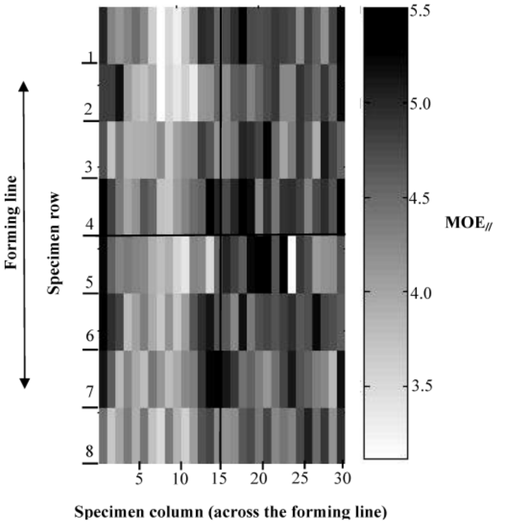
No significant property differences were found between master panels, but significant differences were found within master panels for bending MOE and MOR of the two products (Table 3). This significant within-master-panel variation could arise mainly from the nonuniformity of the formed mat. For the manufacturers, an improvement in forming offers the potential for lowering the average density required and, thus, the production cost while maintaining acceptable panel properties.

Between standard panels.—Table 3 demonstrates that the MOE and MOR between standard panels were significantly different for the two OSB products investigated. Table 4 presents both the average bending property and density values of standard panels, in rank order, which resulted from the LSD test at $\alpha = 0.05$. As shown in Table 4, the parallel bending properties of middle standard panels (panels 8 and 2) of Product A master panels were a little higher, and those of the right-side panels (panels 3 and 9, but especially panel 9) were significantly lower. Similarly, the average $\text{MOE}_{\perp}$ and $\text{MOR}_{\perp}$ for the middle panel (panel 5) was slightly higher than for panels 4 and 6. It seems that the middle standard panels from master panels of Product A were stronger compared with panels from both the left and right side. This is also shown in Figures 3a and 3b.



(a) MOE$_{//}$ of Product A

(b) MOE$_{\perp}$ of Product A



(c) MOE$_{//}$ of Product B

Figure 3.—Plane distribution of MOE within a master panel: (a) MOE$_{//}$ of Product A, (b) MOE$_{\perp}$ of Product A, and (c) MOE$_{//}$ of Product B.

Likewise, significant differences were found in bending properties for standard panels of Product B (Table 4). The average MOE$_{//}$ of standard panels ranged from 4.15 to 4.53 GPa, representing a 9 percent difference from the lowest to the highest values, and the average MOR$_{//}$ ranged from 20.3 to 22.5 MPa, representing an 11 percent difference from the lowest to the highest values. The right-sided panels (panels 2 and 4) had higher bending properties than the left-sided ones (panels 1 and 3), about a 7 percent higher MOE and a 10 percent higher MOR on average. Figure 3c also shows the same trend for MOE distribution within a press opening. This variation between standard panels could result mainly from an improper forming process, as the right side had higher density than the left side (Table 4).

The side-to-side difference in properties often suggests inconsistent strand feeding/alignment of the forming line. For example, the former may discharge more strands on one side than on the other, resulting from the forming head not being leveled, damaged/worn-out picker rolls, or strand plug-up between the alignment disks.

Across the forming line (along the width of a master panel).—The variation and difference in bending properties across the forming line (the width of a master panel) can be determined by the effect of factor ‘‘specimen column.’’ Table 3 illustrates that the bending properties of the two products were significantly affected by the factor specimen column, which means that the difference in the bending properties of specimen columns was statistically significant. These significant differences in MOE between specimen columns along the forming line are also illustrated in Figure 3.

Within the master panel of Product A as shown in Figure 3a, the MOE$_{//}$ of columns ranged from 4.20 GPa (column 42) to 5.59 GPa (column 6) with a difference of 1.39 GPa, whereas the MOR$_{//}$ of these columns varied from 21.8 MPa (column 42) to 31.7 MPa (column 6), with a difference of 9.9 MPa. The differences were 33 and 46 percent, respectively. The MOE$_{//}$ and MOR$_{//}$ of column 42 were both the lowest, and this location was the weakest point of this master panel. There was an area from columns 18 to 23 presenting higher bending properties compared with other areas, coinciding with the LSD result shown in Table 4 that the middle panels of Product A had higher bending

Table 4.—LSD test results of bending properties for standard panels.[a]

Property	Results Product A (11.1 mm thick)						Product B (18.3 mm thick)			
Mean MOE$_{//}$ (GPa)	5.06	5.03	4.98	4.97	4.95	4.87	4.53	4.46	4.24	4.15
Panel ID	8	2	7	1	3	9	4	2	3	1
Mean MOR$_{//}$ (MPa)	27.7	27.6	27.6	27.2	27.2	26.3	22.5	22.3	20.4	20.3
Panel ID	8	1	2	7	3	9	4	2	3	1
Mean density (kg/m^3)	615	607	605	604	602	592	551	540	529	523
Panel ID	1	3	2	7	8	9	4	2	3	1
Mean MOE$_\perp$ (GPa)	2.02		1.93		1.88					
Panel ID	5		4		6					
Mean MOR$_\perp$ (MPa)	14.9		14.3		13.9					
Panel ID	5		4		6					
Mean density (kg/m^3)	603		601		598					
Panel ID	5		6		4					

[a] Panels marked with same line indicate that they have statistically similar properties and are not significantly different at the 0.05 significance level.

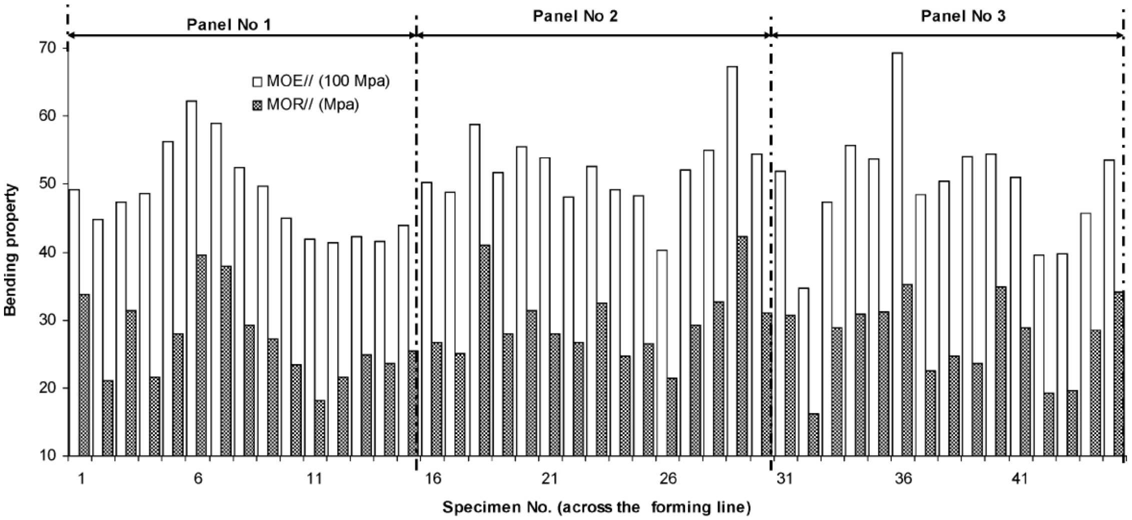
properties. The perpendicular bending properties of Product A also varies from one column to another within a master panel (Fig. 3b). A much lower MOE$_\perp$ of column 1 at the left long edge of Product A was observed. The percentages of increase from the lowest (column 1) to highest (column 4) values of MOE$_\perp$ (1.58 to 2.14 GPa) and MOR$_\perp$ (11.2 to 16.4 MPa) were 35 and 46 percent, respectively. The middle columns (columns 4, 5, and 6) had better overall bending properties than the other columns both in the left and right side of the master panel, which was also illustrated by the results given in Table 4, indicating that the middle panel (panel 5) had the highest perpendicular bending properties.

An OSB panel product with a thickness of 11.1 mm like Product A is commonly used for roof and wall sheathing. In practice, some mills tend to increase the long-edge (about 15-cm) density of the standard panel for this product to enhance sheathing panel edges for improving concentrated static loading and nail-withdrawal capacity. This may result in an uneven distribution of density and, thus, the related parallel bending properties across the forming line. Consequently, higher bending properties at long edges of standard panels may be expected, but for most standard panels of Product A in this study, the MOE and MOR distribution across the forming line were simply random and highly variable (Figs. 3a and 3b).

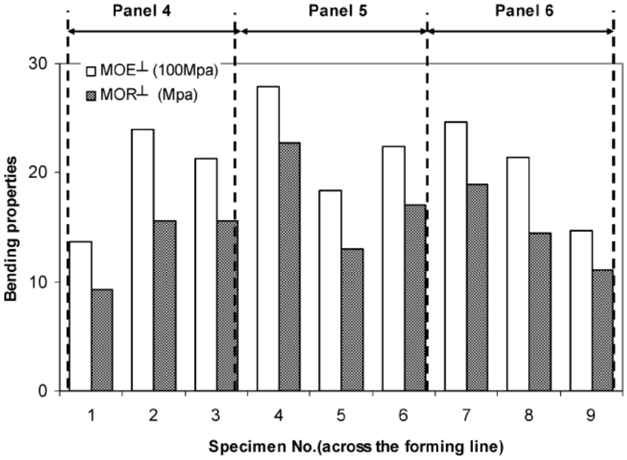
In the case of the 18.3-mm-thick Product B, a uniform density distribution across the forming line is preferred to avoid the large differential swelling if the product is used for subflooring. Hence, the variations in density-related properties, such as MOE and MOR, are expected to be less than those for the thinner products if the density is controlled uniformly. Figure 3c shows how variable the bending MOE$_{//}$ of columns in a master panel of Product B could be. The percentages of increase from the lowest to the highest values of MOE$_{//}$ (3.59 to 4.90 GPa) and MOR$_{//}$ (16.3 to 25.8 MPa) were about 36 and 59 percent, respectively. Figure 3c also illustrates that the middle columns at the left side of the master panel (i.e., columns 8, 9, 10, and 11) were lower in bending properties, which coincides with the LSD results that the left-side standard panels had poorer bending properties than the right-side panels (Table 4).

The bending properties of the specimens within an individual specimen row of a master panel can also demonstrate this significant variation across the forming line. Figure 4 exemplifies the distributions of bending properties within individual specimen rows for the two products. For a specimen row of a master panel of Product A, the MOE$_{//}$ of the specimens ranged from 3.47 to 6.92 GPa, with a difference of 3.45 GPa, whereas the MOR$_{//}$ varied from 16.2 to 42.2 MPa, with a difference of 26.0 MPa (Fig. 4a). The distribution of MOE$_\perp$ and MOR$_\perp$ within an individual specimen row across the forming line of Product A is also illustrated in Figure 4b. The differences from the lowest to highest values of MOE$_\perp$ (1.36 to 2.78 GPa) and MOR$_\perp$ (9.3 to 22.8 MPa) were 104 and 145 percent, respectively. Figure 4c exemplifies a distribution of parallel bending properties across the forming line for Product B. The differences from the lowest to the highest values of MOE$_{//}$ (3.61 to 5.20 GPa) and MOR$_{//}$ (14.2 to 26.8 MPa) were increased by about 44 and 89 percent, respectively.

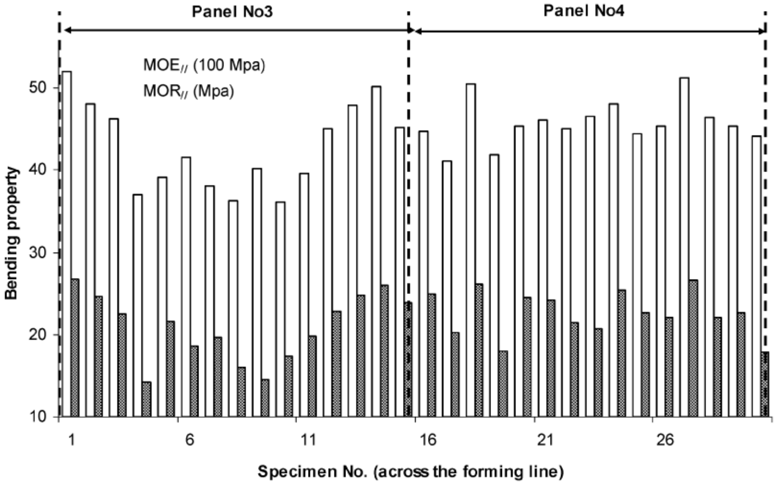
Along the forming line (the length of a master panel).— The difference in bending properties along the forming line (i.e., the length of a master panel) can be evaluated by the effect of factor specimen row. Table 3 demonstrates that the perpendicular bending properties of Product A were not significantly affected by the factor specimen row, while the



(a) Parallel bending property of Product A



(b) Perpendicular bending property of Product A



(c)Parallel bending property of product B

Figure 4.—Distribution of bending properties for a specimen row across the forming line: (a) parallel bending property of Product A, (b) perpendicular bending property of Product A, and (c) parallel bending property of Product B.

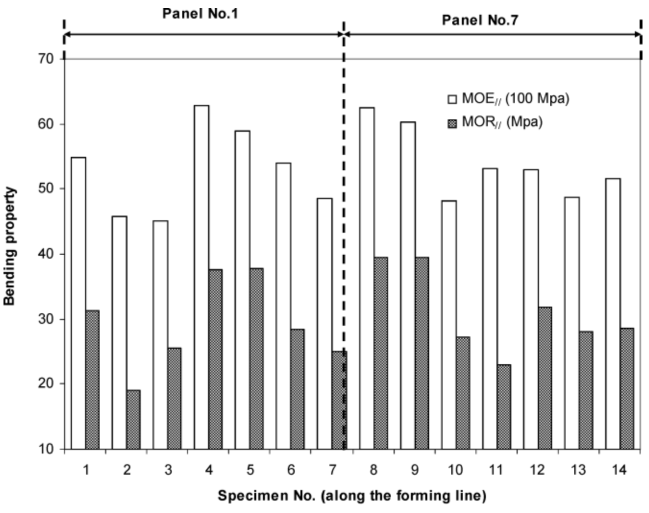
parallel bending properties of both Product A and Product B were significantly different between specimen rows.

For the master panel of Product A shown in Figure 3a, the $MOE_{//}$ of the rows varied from 4.67 GPa (row 2) to 5.27 GPa (row 11), with a difference of up to 13 percent, and the $MOR_{//}$ of the rows fell between 25.4 MPa (row 2) and 29.8 MPa (row 11), with a difference of up to 17 percent. For the rows in a master panel of Product B illustrated in Figure 3c, the differences in bending properties were 8 percent for $MOE_{//}$ and 15 percent for $MOR_{//}$. The specimen rows 1, 2, 3, and 8 on the left side of Product B had much lower $MOE_{//}$ than other areas (Fig. 3c).

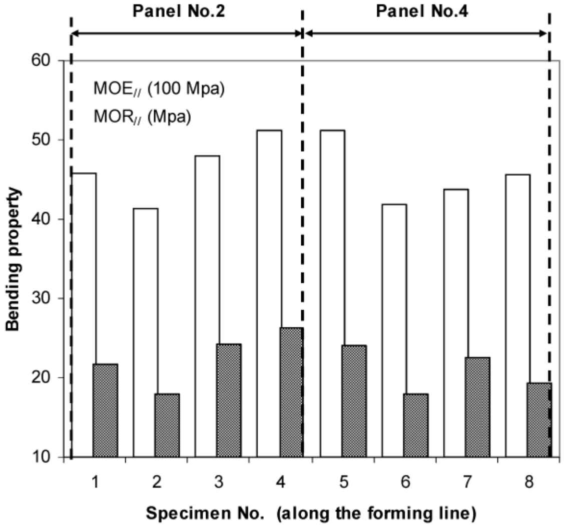
Figure 5 exemplifies the bending property distributions of specimens within an individual column along the forming line. The differences between the lowest and the highest values of $MOE_{//}$ and $MOR_{//}$ were 39 and 107 percent, respectively, for Product A and 24 and 46 percent, respectively, for Product B.

In comparison with the bending properties across the forming line, the bending properties along the forming line had lower variation. This may be attributed, in part, to the fact that the columns (the width of a bending specimen) were narrower than the rows (Figs. 1 and 2).

Correlation between MOE and MOR.—In this study, the specimen rows and columns of higher MOE generally present higher MOR (Figs. 4 and 5). In a previous report (Karacabeyli et al. 1996), a linear correlation with R^2 of 0.7 was observed between mean bending MOR and MOE properties for large specimens of OSB in both directions. For the two OSB products in the present study, linear correlations between MOE and MOR of individual specimens with R^2 around 0.7 were also found (Fig. 6). The results from SAS analysis shows the linear model was valid,



(a) Parallel bending property of Product A



(b) Parallel bending property of Product B

Figure 5.—Distribution of bending properties for a specimen column along the forming line: (a) parallel bending property of Product A and (b) parallel bending property of Product B.

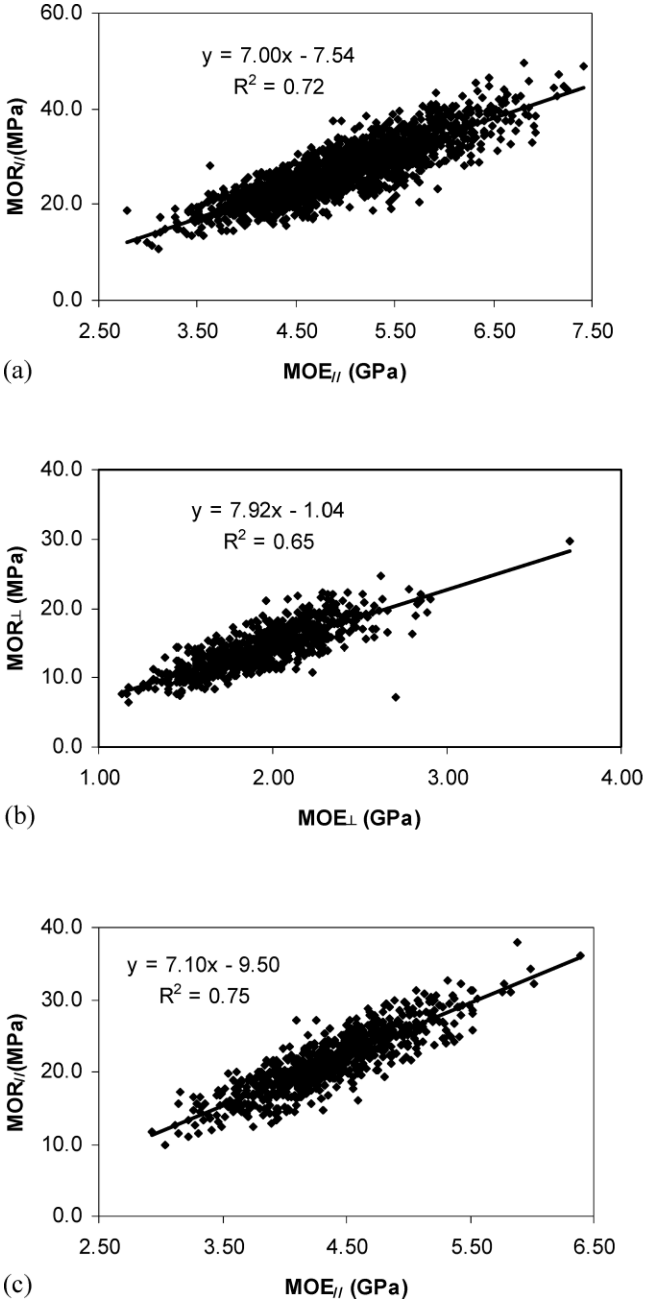


Figure 6.—Correlation between bending MOR and MOE: (a) $MOE_{//}$ and $MOR_{//}$ of Product A, (b) $MOE_{\perp}$ and $MOR_{\perp}$ of Product A, and (c) $MOE_{//}$ and $MOR_{//}$ of Product B.

which was proved by the significance probability of $P < 0.0001$. Thus, a linear relationship could properly describe the correlation between MOR and MOE in this study.

Summary and Recommendation

The bending properties of two commercial OSB products were investigated with a total of 3,420 specimens cut in a continuous order from six master panels. The variations in the bending MOE and MOR in both parallel and perpendicular directions were analyzed using ANOVA and LSD methods. From the data collected, the correlations between MOE and MOR were obtained. Based on the results from two products sampled from two mills, the main findings can be summarized as follows.

1. Thicker OSB panels had less variation in bending properties than thinner panels.
2. No significant differences in bending properties were found between master panels of the two products, but statistically significant variations in bending properties were noted within the master panel (i.e., between standard size panels, along and across the forming line).
3. The differences in mean MOE and MOR of standard panels varied from 4 to 11 percent.
4. The differences in bending properties could range from 8 to 17 percent between specimen rows along the forming line and from 33 to 59 percent between specimen columns across the forming line.
5. The differences in bending properties within a single column along the forming line could vary from 24 to 107 percent, and that within an individual specimen row across the forming line could vary from 44 to 160 percent.
6. The variation in MOE (CV = 12% to 16%) was lower than that in MOR (CV = 20% to 22%), although both properties were correlated in a linear relationship with R^2 around 0.7.

Although the current OSB standards in North America specify no limits, higher variation in general means higher average panel density and product cost for the producers as well as lower product reliability for the designers and consumers. The large spatial variation within a press opening suggests the need for optimization and maintenance of the processing equipment, particularly the forming system.

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