Comparison study of thickness swell performance of commercial oriented strandboard flooring products

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Abstract

The multiple layer structure of oriented strandboard (OSB) has a significant influence on its performance, including thickness swell (TS). TS is recognized as an important performance property for OSB products. Optimization of TS through layer property manipulation to achieve the lowest total TS while maintaining acceptable mechanical properties is attainable if the influence of OSB panel parameters on layer TS is known. In this study, the effect of wood species, resin type, and vertical density profile (VDP) on the total and layer TS were examined. Results from a small sample of commercial OSB panels indicated that aspen OSB exhibited the lowest total TS among the three commonly used materials for OSB panels (southern yellow pine, aspen, and yellow-poplar) in North America. Comparison of the product's VDP indicated the panel characterized with a flat density in the face and core regions and an abrupt drop in density from face to core forming a "u-shaped" profile may provide good dimensional stability (layer TS) due to the structural uniformity in each region. The high-density surface layers placed a significant effect on the panel's total TS. Seventy-three, 70, 65, and 55 percent ofthe total TS occurred in the top and bottom face regions, which accounted for less than 50 percent ofthe panel thickness, at 2-, 8-, 24-, and 96-hour water exposure times. With the increase of water exposure time, face dominating TS decreased. Statistically significant linear relationships were found between the edge TS and TS at 1 inch inside from the edge, which is the standard TS for panel products in ASTM D 1037 at each water exposure time. The difference between the two TSs decreased with the time of water exposure. The trends demonstrated by this research, while not inclusive of all commercial OSB, may be useful for assessing manufacturing process changes to improve TS performance.

Oriented strandboard (OSB) is generally manufactured as a three-layer mat structure for enhanced bending performance. Virtually all OSB is manufactured to achieve performance standards, however, different manufacturers have different process techniques that result in different performance. Comparisons of the performance of commercial OSB in the current market have not been exclusively conducted. A goal of this study was to investigate the effects of manufacturing or product parameters on the dimensional stability of commercial OSB panels. The effects of species and resin type in the panels were examined for flooring products, i.e., 23/32-inch-thick OSB tongue and groove (T&G) panels. A similar study has been done on sheathing products, i.e., 7/l6-inch-thick OSB panels (Wang et al. 2003). Understanding the impact of the product's parameters on performance is important for optimizing structure in the development of new products and improving the manufacturing process.

The multiple-layer structure of OSB has a significant influence on thickness swell (TS). TS is recognized as an important

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performance issue for OSB products. Minimization of TS through layer property manipulation can be aided if the effect of layer TS is known. Traditional TS is measured from a single overall caliper measurement of panel thickness. A new optical layer TS technique makes it possible to measure the effect of the individual layer on the total TS at different water exposure times (Wang and Winistorfer 2002,2003). With this new technique, Wang and Winistorfer found that for nominal 12-mm-thick commercial OSB, the high-density surface which was only 39 percent of the total panel thickness. contributed 74, 64, and 57 percent of the overall TS after 2-, 8-, and 24-hour water exposures, respectively. The surface layers are highly consolidated during hot press closure (i.e., steep density profiles in the faces) to achieve adequate bending properties, therefore exhibiting excessive instability as a swelling response to water exposure. In the previous OSB sheathing products study (Wang et al. 2003), species, wood strand geometry and orientation, and vertical density profiles (VDP) were found to influence mechanical properties, such as modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB) strength. Resin type used in the panels also has an influence. The bottom face was found to swell less than the top face for the 7116-inch OSB products due to the fine strands at the bottom. Similar factors and parameters were examined in this study for 23132-inch-thick commercial OSB flooring panel products.

The overall objective for the study was to optimize total TS performance of commercial OSB panels through layer modification while maintaining acceptable mechanical strength properties. The specific goal of this study was to determine the effect of wood species. resin type, and VDP on the total and layer TS distribution in commercial OSB flooring products (23132 in. thick).

Experimental procedure

Commercial OSB panels

Ten 23132-inch-thick OSB panels manufactured at nine different mills were procured either directly from the mills or the local market. Two different types of core resins and three different material species were chosen to provide a sample of OSB flooring products similar to those currently available in U.S. and Canadian markets. The core resin was either phenol-formaldehyde (PF) or polymeric methylene diphenyle isocyanate (pMDI). Only a few wood species have been used in large quantities for commercial OSB manufacturer. Southern yellow pine (*Pinus* spp.) and aspen (*Populus* spp.) are two common species for OSB. Some dense hardwood species, such as yellow-poplar, have become an alternative material for OSB manufacturers due to their abundance. Test panel specifications are listed in Table 1. Most of the selected flooring OSB products (23/32 in.) in this study were sanded, either on one or two faces. The top and bottom faces were marked based on manufacturers' specification and strand size as observed on the surfaces.

Sample preparation

Test samples were prepared for VDP measurement, water absorption (WA), and TS. Samples were cut from each of the collected OSB panels using a carefully designed cutting pattern to well represent the overall panel properties. Sample dimensions for density, WA, and TS tests were based on ASTM D 1037 (ASTM 2001). Twelve samples 50.8 by 50.8 mm (2 by 2 in) were prepared for the VDP test. Four samples 152 by 152 mm (6 by 6 in.) were prepared for WA and TS tests.

Table 1. - Specification of testing OSB panels.

Testing board no.[a]	Span rating	Species	Core resin[b]
14	24 in OC	Pine	pMDI
15	24 in OC	Pine	PF
16	24 in OC	Pine	pMDI
17	24 in OC	Pine	pMDI
18	24 in OC	Hardwood[c]	pMDI
19	1F24	Aspen	pMDI
20	2R48/2F24	Aspen	PF
21	2R48/1F24	Aspen	pMDI
22	24 in OC	Pine	PF
23	24 in OC	Pine	PF

[a] No. 1 through 13 were assigned to 7/16-inch-thick OSB panels in the previous paper (Wang et al. 2003).
[b] PF = phenol-formaldehyde: pMDI = polymeric methylene diphenyle isocyanate.
[c] Mixture of hardwood species including yellow-poplar, maple, beech, etc.

Testing procedure

Prior to sample preparation, each individual panel was weighed, and thickness measured with a clipper at eight points on the four edges (two on each edge) to obtain the average panel thickness. The overall panel density at the as-received moisture content (MC) was calculated by weight and volume of the panel (average thickness surface area). MC of each panel, as received, was determined by the ovendry method. Therefore the overall normalized panel density was calculated at 0 percent MC for comparison in the analysis.

A commercial x-ray densitometer (QMS Density Profile System QDP-01X) was used to measure VDP of the 12 samples. This is a non-destructive, fast and accurate technique for density profile analysis (Winistorfer et al. 1986).

Total TS at 1 inch in from the edge, total edge TS, WA, and layer TS were measured for each sample after 2-, 8-, 24-, and 96-hour water exposure at a water temperature of 20° ± 1 °C. As in ASTM D 1037, WA and TS tests were done at 2- and 24-hour water submission. Two additional stages of 8 hours and 96 hours of water submission were chosen in favor of investigating the changes in TS. WA was obtained by the difference in sample weight from the initial stage to the particular water exposure time. Total TS was taken at four center points of each side and 1 inch in from the edge of the sample. This is the standard total TS measurement in the ASTM D 1037 or CSA 0437 standard (ASTM 2001, CSA 1993). Edge TS was taken at the midpoint along each edge of the samples. The same location was used for the layer TS measurement. A nondestructive optical technique (Wang and Winistorfer 2002,2003) was used to determine the TS of 23 discrete layers within the intact samples from each test panel. This technique for layer TS determination can help identify the effects of the total TS from the core/face regions, which is undetectable using the overall measurements prescribed by the ASTM and CSA standard method.

Results and discussions

VDP

The density and density profile of OSB is important to its product performance. Local density and density profiles have been shown to have a direct influence on the physical and mechanical properties of the finished products in numerous studies (Kelley 1977, Andrews 1998, Zombori 2001). The most influential parameters on forming VDPs are press closing time, initial MC, and platen temperature (Suchsland 1962; Smith 1982; Kamke and Casey 1988a, 1988b; Zombori 2001, Wang and Winistorfer 2000b). Reduction in density variation can result in improved quality panel products. The effect of VDP on TS is examined here. **Figures 1 and 2** display six OSB panel VDPs consisting of three different species. The two significantly different profiles were chosen from the pine OSB group, panel numbers 14 and 17 **(Fig. 1).** No. 17 showed a steep density profile - two density peaks near the surfaces and wide flat core density region. No. 14 had a much lower core density, and the two narrower peak density regions are not as near to the surface as in panel No. 17. These two different density profiles were expected to give different performance results in the tests. No. 18 with mixed hardwood species flakes had a medium density profile between the two southern yellow pine panels. Only one OSB panel made from a hardwood species was examined in this study. Comparison within this group could not be conducted. Density profiles of the three aspen panels **(Fig. 2)** demonstrated three significantly different processing techniques when making the panels. Panel Nos. 19 and 2 1 had steep density profiles and wide low density core regions. The difference between the two profiles was that Panel No. 2 1 had two relative flat shoulders at the surface areas instead of two narrow peak densities as in No. 19. No. 20 had a less steep density profile with high narrow core density and two peak surface densities pushed in toward the center. Smith (1982) has proposed u-shaped and m-shaped density profiles are a function of press closing time. A fast closing rate (30 sec) results in a u-shaped density profile and a slow closing rate (100 sec) gives a m-shaped density profile. In the aspen panels tested for this study, it is obvious that No. 2 1 has a u-shaped density profile and No. 20 has a m-shaped density profile. The TS performance of these panels was expected to be different due to the significantly different density profiles.

Total TS

Total TS in this study was measured at both 1 inch inside from each edge and on the edge at the midpoint of each side. The results are shown in **Table 2** at the four water exposure times.

After 2 hours of water exposure, the 1 inch inside TS of ten 23132-inch panels ranged from 0.55 to 7.86 percent. Panel No. 14 exhibited the largest TS (7.86%), seven times higher than 0.96 percent of Panel No. 21. After 96 hours ofwater exposure, the difference in total TS between the two panels decreased to slightly over two times (34.8% and 12.56%, respectively). The difference in total TS between good and poor OSB panels decreased with the time of water exposure. This trend was also observed in the previous 711 6-inch OSB panel test.

OSB panels from the aspen group had a lower overall TS at all water exposure times than those of the pine group. The reason for this may be the specific gravity (SG) of these two species. Aspen has a lower SG than most pine species, which re-

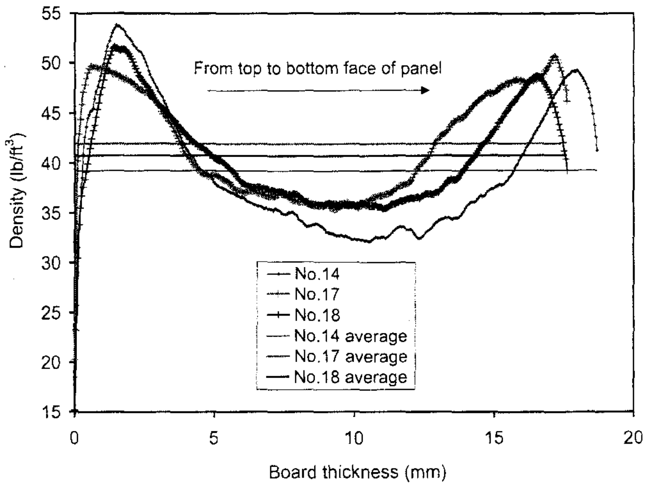

Figure 1. - VDP for OSB 23/32-inch-thick panels, two pine species (No. 14 and 17) and one hardwood mixed species (No.18).

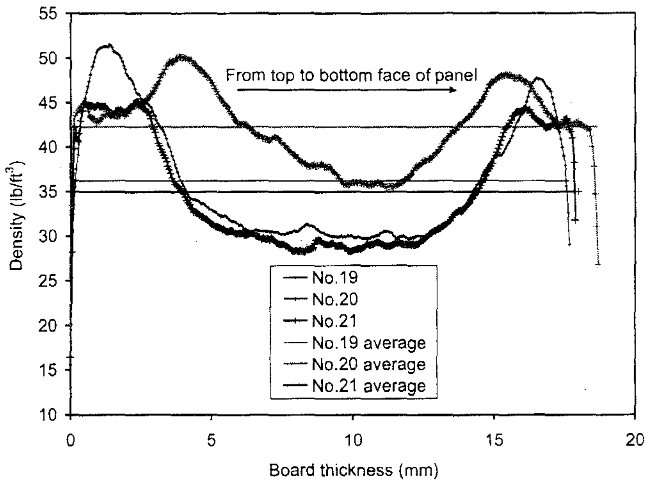

Figure 2. - VDP for three 23/32-inch-thick aspen OSB panels.

sults in a higher compaction ratio for aspen panels than pine panels after the hot-pressing process. The higher compaction ratio gives aspen panels a relatively uniform profile in both vertical and horizontal density distribution. which reduces the TS from the unbalanced internal stresses caused by density distribution.

Panel No. 17 displayed the lowest total TS in the pine group. and No. 14 showed the highest total TS in the group, while the average panel density of No. 17 is higher than that of No. 14 **(Table 2).** Examining the VDPs of the two panels **(Fig. 1),** it was found that No. 17 had a VDP of less intensive change. with a slow change in the surface region, relatively uniform density in the core, and less difference between the peak and foot density. No. 14 had two narrow peaks next to the surface, a large difference between the peak density and foot density, and a less steep drop from face to core. A similar trend was found in the aspen panel group. No. 20 had significantly higher TS than No. 21 **(Table 2).** No. 21 had a u-shaped density profile with relatively uniform density in the face and core regions (Fig. 2). No.

Table 2. - Total TS and WA of commercial 23/32-inch-thick OSB panels.

Test board no	Density (0% MC)	1-inch inside TS (%) 2 hours	8 hours	24 hours	96 hours	Edge TS (%) 2 hours	8 hours	24 hours	96 hours	WA(%) 2 hours	8 hours	24 hours	96 hours
						Pine group							
14	36.61	7.86	17.05	27.55	34.80	13.52	23.11	29.96	35.10	21.88	39.22	60.94	8498
15	38.55	4.29	6.06	13.40	26.89	7.67	14.44	22.44	27.88	10.01	17.08	29.13	64.41
16	38.16	2.37	3.25	4.77	13.36	3.43	5.55	8.87	17.19	5.25	7.20	10.45	35.24
17	39.51	3.48	3.28	5.90	12.72	2.75	4.80	8.22	15.20	5.28	7.44	11.02	36.14
22	33.07	2.74	6.94	10.30	18.92	6.46	11.08	14.98	19.65	13.84	21.60	34.15	63.38
23	35.23	3.62	6.34	9.59	16.28	5.60	9.71	13.28	17.51	10.22	18.39	30.23	55.02
Avg.	36.85	4.06	7.16	11.92	20.49	6.57	11.45	16.29	22.09	11.08	18.49	29.32	56.53
						Aspen group							
19	34.06	0.55	2.83	6.71	17.59	4.37	9.75	15.53	22.19	5.85	12.07	25.70	62.16
20	39.72	2.07	4.94	9.01	21.74	6.32	12.27	18.66	27.66	6.80	13.23	25.03	55.97
21	33.08	0.96	1.82	4.46	12.56	2.96	6.39	10.12	14.96	4.67	8.89	19.86	51.22
Avg.	35.62	1.19	3.20	6.73	17.30	4.55	9.47	14.77	21.60	5.77	11.40	23.53	56.45
						Hardwood group							
18	38.11	0.71	3.12	7.18	18.84	4.19	9.62	14.90	23.53	6.12	12.13	26.69	56.16

20 had a m-shaped density profile with two density peaks pushed inside from the surface. The density profile in each region (face and core) of panel No. 20 was less uniform than panel No. 21. This was one of the reasons that the total TS of No. 20 was higher than No. 21. Another important reason was the overall density of No. 20 was much higher than that of No. 21 **(Table 2).** From the comparison within the two groups, it was found that reducing the variations in OSB VDPs appeared to be an effective way to improve the products' performance in dimensional stability.

Also shown in **Table 2** is that both edge TS and WA in relation to water exposure time were similar to the 1 inch inside TS. The edge TS was higher than the 1 inch inside TS due obviously to the measuring location. The difference between the two decreased as the water exposure time increased. The linear positive correlation (shown in **Fig. 3)** between the two TSs discovered in this study confirms the previous 7116-inch OSB study result (Wang et al. 2003). This relationship may help manufacturers easily and quickly predict maximum TS on the edges with the value of the 1 inch inside TS measured by ASTM standards.

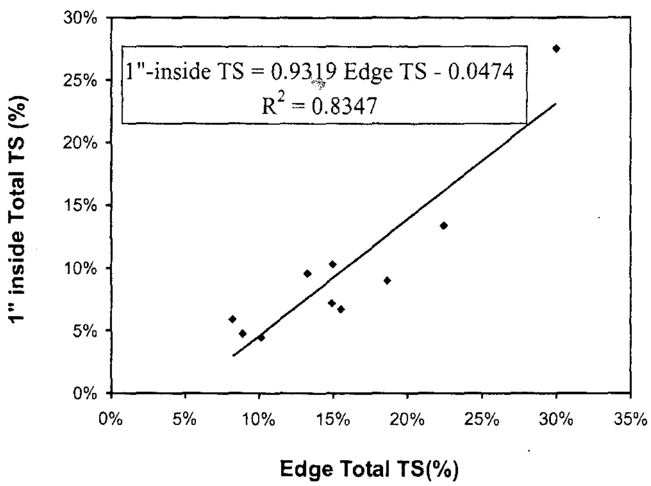

Figure 3.-Correlations between the edge total TS and 1 inch inside total TS for the 23/32-inch-thick OSB panels after 24 hours of water exposure.

Layer TS

Without knowing the TS performance of an individual layer within a panel, reduction of total TS can be elusive. With the development of a nondestructive optical technique (Wang and Winistorfer 2002,2003) for individual layer TS measurement, 21 0.8-mm-thick layers in 23/32-inch panels were examined for swelling responses at the four water exposure times. All of the panels showed higher TS in the layers near the surfaces due to the high density in that region. Layer TS correlated well with the density profile. Two panels, No. 14 and No. 17, with the highest and lowest total TS in the pine OSB group are plotted in Figure 4. No. 20 and No. 21 with the highest and lowest TS in the aspen group are plotted in **Figure 5.** The highest TS panel in each group (No. 14 and No. 20) exhibited more dramatic changes in TS from one layer to the next, especially after a 96-hour water soak. This could be a result of less uniform density distribution of strands in the panel thickness and delaminations occurred between unbalanced swelling layers. The two lowest TS panels, No. 17 and No. 21, in the pine and aspen groups showed less of a difference in TS from one layer to the next, and a relatively uniform TS in the core region. The layer TS change in each panel indicates that better dimensional stability comes from the panel with uniform density in each region (face and core) and density peaks located closer to the surface.

Shell ratios (the ratio on a weight basis of face material to core material) for the test panels in this study were unknown

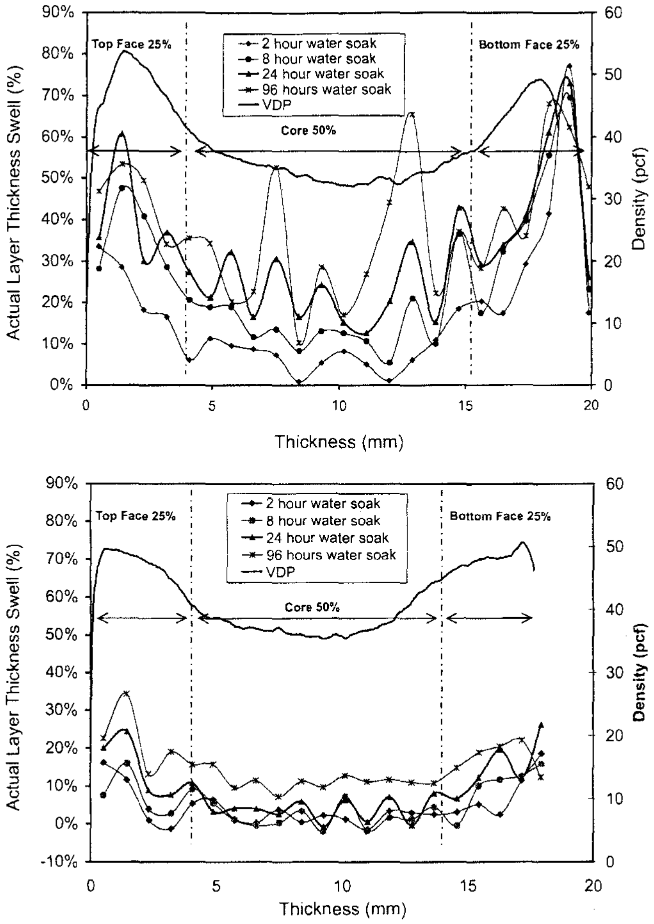

Figure 4. - Actual TSs on individual layers of two pine OSB panels: No. 14 (PF resin in face, pMDl resin in core) (top) and No. 17 (PF resin in face, pMDl resin in core) (bottom).

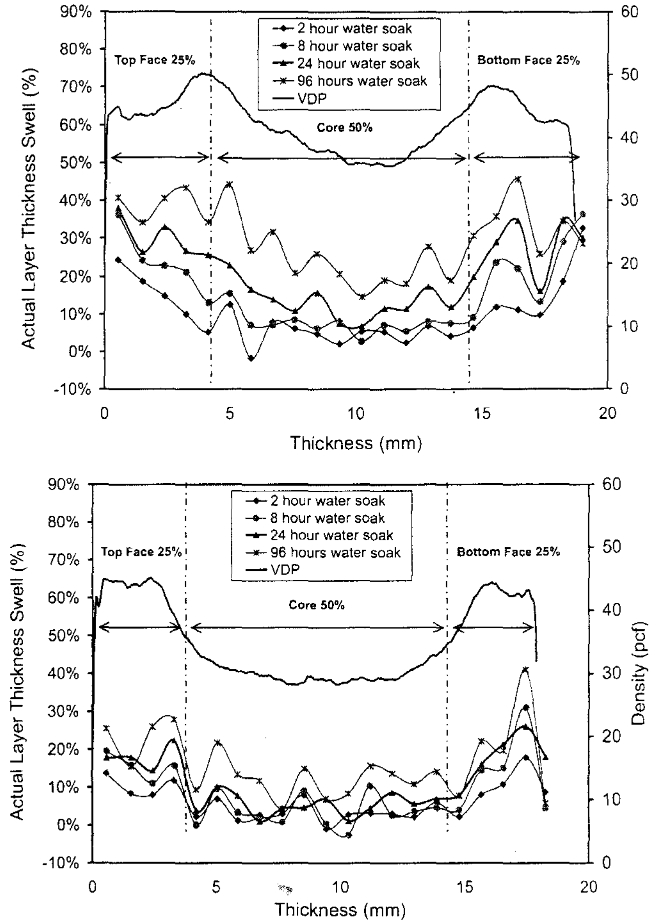

Figure 5. - Actual TSs on individual layers of two aspen OSB panels. No. 20 (PF resin in face, PF resin in core) (top) and No 21 (PF resin in face, pMDl resin in core) (bottom)

from commercial boards. Each mill usually uses a slightly different shell ratio to achieve suitable bending proptrties in both the parallel and perpendicular directions. Most mills use shell ratios between 30-40-30 percent and 25-50-25 percent for 23/32-inch OSB flooring products. Thus these two ratios were assumed in the study for the face/core TS analysis. Panel thicknesses were divided into two face regions (top and bottom) and one core region based on the weight ratio of 30-40-30 percent or 25-50-25 percent. The trend from the two ratio analyses is the same. Therefore. only the 25-50-25 percent case is discussed here. The actual marks for face and core region on the panel thickness were calculated based on the VDP data by making the weight of each face region 25 percent of the total panel weight. Thus the actual high-density face regions will not be exactly 50 percent of the total thickness but less than 50 percent of the panel thickness due to the VDP. The 23132-inch OSB panels were divided into 21 equally thick layers for layer thickness analysis as discussed above. For the 25-50-25 percent weight-base ratio, the top face region consisted of layers 1 to 4 and part of layer 5. The bottom face region consisted of layers 18 to 21 and part of 17. The rest of the layers formed the core region.

Table 3 shows the effect of the face and core regions on the total TS from the average of the 10 panels. The average for the top, core, and bottom face TSs at the four water exposure times are 36-27-37 percent (2 hr), 35-30-35 percent (8 hr), 34-35-31 percent (24 hr), and 30-45-25 percent (96 hr). It was demonstrated that, at the early stage of water exposure, about 73 percent of the total TS occurred in the face regions which only makes up 50 percent of the total panel thickness. Even after 24 hours of water exposure, an average of 65 percent of the total TS still occurred in the face regions. The impact of nonuniform densification in the face regions developed during the pressing process is believed to be the factor. When the water exposure time increased, the dominance of the face region in total TS decreased. Given enough water exposure time, the ratio of face to core TS should approach the panel shell ratio.

Table 3 - Percent contributions of face and core TS to the total TS.

	Shell ratio (25%:50%:25%)		
	Top face	Core	Bottom face
Water exposure time	(layers 1 to 4 and part of layer 5)	(part of layer 5 layers 6 to 16, part of layer 17)	(pan of layer 17 and layers 18 to 21)
(hr)		(%)	
2	35 29	27.11	37 60
8	34.80	29 67	35 52
24	32 30	35 41	32 24
96	28 54	44 81	26 66

Table 4. - Percent contributions of face and core TS to the total TS, compared by the material species in the parrels.

	Shell ratio (25%:50%:25%)		
	Top face	Core	Bottom face
Wood species	(layers 1 to 4 and part of layer 5)	(part of layer 5, layers 6 to 16, part of layer 17)	(part of layer 17 and layers 18 to 21)
	2-hour water soak		
Pine group	34.65%	27.05%	38.30%
Aspen group	35.97%	30.19%	33.84%
	8-hour water soak		
Pine group	33.32%	31.08%	35.60%
Aspen group	36.69%	28.35%	34.96%
	24-hour water soak		
Pine group	32.98%	36.03%	30.99%
Aspen group	33.70%	34.25%	32.05%
	96-hour water soak		
Pine group	30.02%	44.32%	25.66%
Aspen group	30.14%	44.11%	25.75%

Table 5. - Percent contributions of face and core TS to the total TS, compared by the core resin in the panels.

	Shell ratio (25%:50%:25%)		
	Top face	Core	Bottom face
Resin type	(layers 1 to 4 and part of layer 5)	(part of layer 5, layers 6 to 16, part of layer 17)	(part of layer 17 and layers 18 to 21)
	2-hour water soak		
pMDI	36.09%	26.22%	37.69%
PF	35.78%	28.44%	35.77%
	8-hour water soak		
pMDI	34.74%	28.41%	36.86%
PF	35.34%	31.58%	33.08%
	24-hour water soak		
pMDI	33.87%	34.00%	32.13%
PF	32.74%	37.66%	29.30%
	96-hour Water soak		
pMDI	29.27%	45.52%	25.20%
PF	30.87%	43.73%	25.40%

Table 4 compares face/core TS between the pine and aspen groups at the four water exposure times. The pine panels, compared to aspen panels, exhibited higher TS effects at the face regions, thus there was relatively less effect from the core region after 2 hours of water soaking. Aspen panels began increasing TS in the face region after the 8-hour water soak, which reduced the effect from the core region in the total TS. Thereafter, both groups began to swell from the face region to core region, which increased the core TS percentage as demonstrated in **Table 4.** At 96-hours water exposure, the face/core contribution to the total TS in the two groups did not exhibit any difference. This indicated that during the water-soaking period, OSB pine panels generated TS faster than aspen panels from face to core.

To compare the face/core effect on the total TS between the panels made with two resin types, **Table 5** shows the percentage of the face/core TS values at the four water exposure times. Panels with MDI as the core resin consistently exhibited lower core TS than the panels with PF core resin until 96 hours water soaking. The face/core percent in the total TS in the two resin type panels became similar after 96 hours of water exposure. MDI resin type panels even exhibited a slightly higher core TS than PF resin panels at 96-hour water exposure.

In regards to the top and bottom face TS in OSB products, consistently higher TS in the top face than in the bottom face was found in a previous study on 7/16-inch OSB panels. This was likely due to more fine strands shaken down to the bottom face during the mat-forming process, resulting in a relatively uniform structure in the bottom region. The 23/32-inch OSB products studied in this test showed varied trends for the face and bottom TS **(Table 3).** The three panels, Nos. 18, 19, and 20, without any surface sanding, showed consistently higher TS in the top face than in the bottom face for all water exposure times. This is consistent with what was found in the 7116-inch OSB products. All the rest of the 23/32-inch test panels, with either one side sanded or both sides sanded, did not have consistent change on either the top or bottom face. This can be traced to an inconsistent and unknown amount of material being sanded from the product's top or bottom faces.

Conclusions

1. Overall the aspen OSB panels had lower average total TS at all water exposure times than the southern yellow pine group due to the species SG. Analysis on the face/core percentage in the total TS between the two groups of panels indicated that pine OSB panels generated TS faster than aspen panels from face to core region.
2. Individual layer TS comparisons showed that the more uniform (flat) density profiles in each of the three regions (two faces and core) resulted in less variations in layer TS, and in turn lower total TS. Panel Nos. 17 and 21 exhibited the lowest total TS in the pine and aspen panel groups, respectively. The panel product with the VDP characterized as flat in each of the three distinct regions and u-shaped profile may exhibit good dimensional stability.
3. For the 25-50-25 percent shell ratio of the 23132-inch OSB testing panels, about 73 percent of the total TS occurred in the top and bottom face regions at the early stage of water exposure, which only takes up less than 50 percent of the total thickness. After 24 hours of water exposure, an average of 65 percent of the TS occurred in the face regions. With the increase of water exposure time, the effects from the face regions decreased, i.e., total TS is less dominated by the face.
4. The TS in the top face was higher than that in the bottom face at any water exposure time for the panels without sanding on either surface. This result agrees with the previous study for 7/16-inch panels. Panels with sanding, ei-

ther on one or two faces, did not have consistent changes in the top and bottom face TS.

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