EFFECTS OF SILVICULTURAL PRACTICE AND VENEER LAYUP ON SOME MECHANICAL PROPERTIES OF LOBLOLLY PINE PLYWOOD

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ABSTRACT

Loblolly pine three-ply plywood was manufactured from veneer obtained from silviculturally different stands. Panels from each site were assembled with four different veneer grade arrangements and tested in wet and dry conditions. Stiffness properties in both the wet and dry conditions and strength properties in the dry condition were all significantly affected by silvicultural practice; veneer grade arrangement also showed significant differences. Shear strength and bending properties (MOR and MOE) were most favorable with panels manufactured from all A-grade veneer (AAA). Strength properties were found to be very similar between panels manufactured with A-grade veneer on one face and C-grade veneer on the other face and in the core (ACC), and A-grade veneer on both faces and C grade veneer in the core (ACA).

Southern yellow pine (SYP) plywood is an accepted building material and is used in numerous structural and nonstructural applications. With the inevitable increase in world population, SYP plywood production will need to continue to become more efficient. Numerous investigations have been conducted to improve the quality of this wood composite panel. Many have focused on improving plywood adhesives and hot-pressing technology.

Research addressing the effect of silvicultural practice on SYP plywood is sparse. MacPeak et al. (8) found that plywood manufactured from veneer cut from fast-grown trees (20 to 25 years old) had mechanical properties that were marginal in terms of stiffness and modulus of elasticity and reduced for bending strength. Research addressing the effect of different veneer grades within the panel is also sparse for SYP bending properties. Biblis and Lee (4) reported on the effect of veneer quality and moisture content (MC) on the compressive, but not on bending, properties of SYP plywood and found a significant increase in compressive strength of three-ply SYP plywood by improving the grades of the face veneers from C and D to B.

The objectives of this research were to 1) determine the effect of silvicultural practices on SYP plywood strength properties; 2) evaluate the effect of different veneer grades within a panel; and 3) examine the effect of moisture level on bending properties.

MATERIALS AND METHODS

A detailed description of the veneer and the processing methods is described by Shupe et al. (11) and the stands by Baker and Bishop (3). A brief summary is presented here. Five representative trees, each from five silviculturally different loblolly pine (*Pinus taeda* L.) stands growing near Crossett, Ark., were harvested and bucked into peeler bolts. Three of the silvicultural regimes were even-aged and consisted of stand 1 (sudden sawlog), stand 2 (conventional), and stand 3 (natural regeneration). The uneven-aged stand investigated was subdivided into two tree age classes: stand 4 (single tree selection) and stand 5 (crop trees).

Full size (54- by 98-in.) loblolly pine

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A- and C-grade, 1/8-inch-thick veneer sheets from each stand were randomly selected and a 21-in.[2] piece was cut with the grain parallel in one direction. The veneer had been commercially dried to 6 to 8 percent MC. Three-ply plywood panels were produced from veneer from each stand with four different layups. The layups were: 1) all A-grade veneer (AAA); 2) all C-grade veneer (CCC); 3) A-grade veneer on one face only and C-grade veneer on the other face and core (ACC); and 4) A-grade veneer on each face and C-grade veneer in the core (ACA). Four panels (21 in. by 21 in.) were manufactured for each specific veneer layup from each of the five stands. Phenol-formaldehyde resin (43% solids) was spread at 75 pounds per 1,000 ft.[2] of double glueline and the veneers were immediately assembled into three-ply panels with the tight side facing out on each face veneer. The open assembly time was minimal in order to resemble full-size plant manufacturing conditions. After sandwich assembly, panels were prepressed for 25 minutes at 10 psi. Panels were then hot-pressed for 2 minutes at a platen temperature of 285°F and 175 psi. As the panels were removed, they

TABLE 1. — Mean mechanical and physical property values for southern pine plywood produced from five stands according to four layup patterns.[a]

		Dry condition (40% RH, 110°F)			Wet condition (24-hr. water soak)				
Stand-layup[b]	Latewood	SG (MC%)	MOR	MOE	MOR	MOE	SG (MC%)	Thickness swell	Width swell
	(%)		(psi)	(× 10⁶ psi)	(psi)	(× 10⁶ psi)		(%)	(%)
1-AAA	60.19	0.70	15,650	2.46	5,373	1.49	0.70	13.54	1.42
	(9.67)[c]	(7.36)	(1.97)	(1.20)	(0.86)	(1.15)	(36.21)	(1.29)	(1.33)
1-CCC	77.08	0.66	10,847	1.87	4,087	1.15	0.65	12.74	1.79
	(1.55)	(7.28)	(2.57)	(1.72)	(1.25)	(1.88)	(36.29)	(1.32)	(5.67)
1-ACA	49.76	0.69	13,104	2.12	4,913	1.21	0.67	14.78	1.30
	(1.91)	(7.26)	(1.76)	(1.14)	(1.00)	(1.13)	(38.27)	(1.25)	(1.82)
1-ACC	52.58	0.64	13,104	2.07	4,274	1.00	0.67	14.94	1.40
	(2.23)	(7.97)	(1.76)	(1.60)	(2.51)	(1.30)	(37.19)	(3.53)	(4.28)
2-AAA	65.34	0.69	15,900	2.57	5,163	1.46	0.69	13.85	1.75
	(4.30)	(8.38)	(0.75)	(0.77)	(0.69)	(1.07)	(35.33)	(0.53)	(1.33)
2-CCC	46.83	0.68	13,563	2.22	4,806	1.23	0.67	15.65	1.80
	(13.45)	(8.16)	(1.38)	(1.32)	(1.43)	(1.22)	(36.53)	(1.25)	(1.27)
2-ACA	41.31	0.68	14,312	2.41	4,678	1.39	0.68	17.98	1.97
	(10.59)	(8.69)	(1.34)	(0.87)	(2.64)	(1.21)	(37.48)	(4.80)	(1.25)
2-ACC	59.08	0.69	12,256	2.35	4,698	1.34	0.67	14.36	1.63
	(9.64)	(8.33)	(2.34)	(0.85)	(0.81)	(1.84)	(34.45)	(1.48)	(1.98)
3-AAA	56.02	0.69	14,126	2.35	5,158	1.41	0.70	12.28	1.31
	(1.19)	(8.34)	(1.27)	(0.50)	(0.86)	(1.30)	(35.27)	(1.71)	(1.44)
3-CCC	60.84	0.61	9,879	1.74	4,610	1.18	0.62	12.50	1.26
	(2.98)	(8.19)	(2.99)	(1.50)	(1.96)	(1.37)	(38.26)	(1.52)	(2.18)
3-ACA	62.20	0.66	14,902	2.31	5,161	1.52	0.63	11.24	1.44
	(2.98)	(8.00)	(0.93)	(0.53)	(1.14)	(1.85)	(40.27)	(1.38)	(2.94)
3-ACC	63.83	0.62	11,620	1.99	4,679	1.24	0.63	11.24	1.44
	(2.70)	(8.79)	(2.49)	(1.42)	(2.29)	(1.07)	(38.27)	(1.38)	(2.94)
4-AAA	69.71	0.70	13,139	2.00	6,269	1.65	0.71	8.94	1.91
	(5.19)	(7.49)	(2.10)	(1.78)	(1.57)	(1.98)	(38.41)	(1.89)	(1.61)
4-CCC	43.30	0.66	9,691	1.85	5,148	1.43	0.67	11.40	1.99
	(3.92)	(7.45)	(2.08)	(1.30)	(1.66)	(1.59)	(36.26)	(2.21)	(1.70)
4-ACA	67.48	0.71	14,375	2.34	5,661	1.58	0.69	9.53	1.96
	(2.07)	(7.13)	(1.49)	(1.35)	(1.22)	(1.43)	(37.40)	(1.85)	(1.38)
4-ACC	62.75	0.71	11,275	2.21	5,748	1.66	0.70	9.27	1.84
	(5.08)	(7.58)	(3.04)	(0.93)	(1.97)	(1.65)	(39.44)	(1.36)	(2.41)
5-AAA	59.70	0.69	14,853	2.34	5,342	1.51	0.68	10.84	1.80
	(2.21)	(7.78)	(1.31)	(0.91)	(0.94)	(1.03)	(35.34)	(1.37)	(1.80)
5-CCC	62.59	0.60	10,952	1.66	4,703	1.24	0.61	9.76	1.60
	(4.05)	(7.54)	(1.16)	(1.05)	(1.38)	(1.19)	(37.18)	(1.03)	(1.74)
5-ACA	56.53	0.60	10,290	1.78	5,788	1.26	0.73	10.62	1.79
	(2.29)	(7.96)	(6.98)	(4.90)	(0.65)	(1.49)	(38.35)	(1.96)	(4.05)
5-ACC	48.64	0.61	11,254	1.72	4,697	1.29	0.62	8.60	1.39
	(7.20)	(7.74)	(1.35)	(0.73)	(1.03)	(1.93)	(39.40)	(1.58)	(2.10)

[a] Latewood and SG values represent the mean of 3 samples, all other values represent the mean of 12 samples.
[b] Stand 1 = sudden sawlog; stand 2 = conventional; stand 3 = natural regeneration; stand 4 = single tree selection; stand 5 = crop trees.
[c] Values in parentheses are coefficients of variation (%), except for SG column, where values in parentheses are the percent MC.

were placed in a hot-stack box where they remained overnight. Most panels were compressed to a thickness near 5/16-inch (.3125 in.).

Panels were edged to 19-in.[2] dimensions. Six bending specimens (1 in. by 19 in.) were cut from each panel. The remaining portion of each panel was cut into shear samples (1 in. by 3.25 in.) (1). All bending samples were conditioned to the nominal MC of 7.2 percent at 40 percent RH and 100°F in an Aminco chamber. From each panel, three bending specimens were tested at approximately 7 percent MC, and three were tested in a wet condition (after a 24-hr. water-soak) (2). The width and thickness of all samples were measured at three approximately evenly spaced locations with a digital caliper to the nearest 0.0001 inch. The average of these three measurements was used for subsequent mechanical and physical property determination. The 24-hour soak bending samples were measured before and after soaking to determine width and thickness swell. Swelling was determined as a percentage of dimension increase from the original dry dimensions (7% MC).

We tested 390 shear specimens for each stand. One third of the shear samples from each stand were allocated to one of three shear tests and all were tested wet. The vacuum-soak samples were placed in a pressure vessel and submerged in water at 120°F with a vacuum of 15 inches of Hg. After the vacuum was released, the samples continued to soak for 15 hours at atmospheric pressure. The boil-dry-boil samples were boiled in water for 4 hours and then dried for 20 hours at 145 ± 5°F and then boiled again for 4 hours and cooled in water. The vacuum-pressure samples were subjected to 25 inches of Hg for 30 minutes, then 65 to 70 psi pressure for 30 minutes (1).

At the conclusion of shear testing, all samples were ovendried and the percentage of wood failure was visually estimated. From each stand, three shear samples were randomly selected and cut to 0.25-inch lengths. The widths and thicknesses remained approximately 1 inch and 0.375 inch, respectively. These samples were sanded on the ends (1- in. by 0.375-in. faces) and placed on a Hewlett-Packard ScanJet IIc/ADF image scanner, which produced a digitized black and white image that was transferred to a computer algorithm to determine the percentage of black (latewood) and white (earlywood) in the image.

Static bending tests were centrally loaded and conducted over an 18-inch span with a crosshead speed of 0.19 inch/minute using a computer-driven software package on an Instron testing machine with an MTS upgrade. All samples were symmetric with respect to veneer grade arrangement except ACC. The ACC samples were consistently tested with the A-grade veneer on the compression side and the C-grade veneer on the tension side during the bending tests for uniformity. The software package allowed for data to be downloaded and analyzed using a factorial analysis on SAS (10). Tukey's Honest Significant Difference test was employed to determine significance between means.

TABLE 2. Factorial analysis of modulus of rupture (MOR) and modulus of elasticity (MOE) of three-ply loblolly pine plywood.

		MOR - *p*-values[a]		MOE - *p*-values[a]	
Source of variation	df[b]	Dry condition	Wet condition	Dry condition	Wet condition
Stand (site)	4	0.1639	0.0002**[c]	0.0152*[c]	0.0027**
Layup	3	0.0031**	0.0005**	0.0063**	0.0036**
Stand × Layup	12	0.0096**	0.7218	0.0002**	0.0110*

TABLE 3. — Basic physical and mechanical properties in the dry condition and MOR and MOE reduction in the wet condition of three-ply loblolly pine plywood.[a]

		Dry condition (40% RH, 110°F)				Wet condition (24-hr. water soak)				
Stand[b]	Latewood	MC[c]	SG[d]	MOR	MOE	MC	MOR	MOE	Thickness swell	Width swell
	(%)			(psi)	(× 10[6] psi)	(%)	(psi)	(× 10[6] psi)	(%)	(%)
1	57.15[e]	7.2	0.67	13,202 AB[f]	2.13 B	28.8	4,692 B	1.22 C	13.99 A	1.60 A
	(2.15)			(0.53)	(0.40)		(0.41)	(0.45)	(0.49)	(0.98)
2	53.14	7.3	0.68	14,008 A	2.39 A	28.9	4,836 B	1.36 B	15.46 A	1.58 A
	(2.54)			(0.41)	(0.26)		(0.39)	(0.37)	(0.75)	(0.38)
3	60.72	7.3	0.65	12,632 B	2.10 B	30.0	4,891 B	1.34 BC	12.04 B	1.54 A
	(0.70)			(0.56)	(0.35)		(0.43)	(0.41)	(0.35)	(0.61)
4	60.81	7.4	0.69	12,120 A	2.10 B	27.7	5,706 A	1.58 A	9.79 C	1.52 A
	(1.76)			(0.61)	(0.38)		(0.42)	(0.36)	(0.51)	(0.43)
5	56.86	7.7	0.63	11,827 B	1.86 C	26.1	4,927 B	1.38 B	9.62 C	1.58 A
	(1.19)			(0.68)	(0.56)		(0.32)	(0.36)	(0.43)	(0.60)

[a] Latewood, MC, and SG values represent the mean of 12 samples; all other values represent the mean of 96 samples.
[b] Stand 1 = sudden sawlog; stand 2 = conventional; stand 3 = natural regeneration; stand 4 = single tree selection; stand 5 = crop trees.
[c] Moisture content (%) ovendry basis.
[d] Specific gravity based on volume and weight at 40 percent RH and 110°F.
[e] Values in parentheses are coefficients of variation (%).
[f] Means followed by the same capital letter are not significantly different (Tukey test).

RESULTS AND DISCUSSION

BENDING PROPERTIES: SILVICULTURAL EFFECTS

Mean mechanical and physical values for all different stand and layup combinations are given in **Table 1**. The results of the factorial analyses of the bending strength data are summarized in **Table 2**. The stand effect is a significant source of variation for modulus of rupture (MOR) and modulus of elasticity (MOE) of the wet samples and for the MOE of dry samples. The moduli in both wet and dry conditions were significantly affected by the layup of veneer grades in the panels.

Significant differences in mechanical properties attributable to the stand effect were anticipated due to the heterogeneity of the five silvicultural strategies employed on each of the five stands and the differing stand ages. The mean latewood percentage from the five stands ranged from 53 to 61 percent and seems not to be influential for mechanical properties (**Table 3**).

Stand 2 (conventional) gave the highest dry MOR (14,008 psi) and was significantly superior for MOE in the dry condition. This finding is important in that a conventional SYP stand, which was managed for lumber production, yielded plywood MOR that was 6 and 10 percent higher, respectively, than stand 1 (sudden sawlog) and stand 3 (natural regeneration). The sudden sawlog silvicultural method is considered advantageous for rapidly producing sawlogs, but appears less favorable for plywood. Therefore, due to the favorable performance of the conventional stand, our finding suggests that foresters will not need to segregate stands for either end product (lumber or plywood), but simply continue to manage in a traditional manner and produce whatever product is most economically advantageous at harvest.

Stand 1 (sudden sawlog) (13,202 psi) and stand 3 (natural regeneration) (12,632 psi) were not significantly different from stand 2 (conventional) for MOR in terms of Tukey groupings. The sudden sawlog silvicultural method was designed to produce sawlog-size logs as rapidly as possible. However, it appears that while the quantity of timber is relatively high for stand 1 (sudden sawlog) (basal area = 90 ft.^{2}/acre), the quality of plywood from this stand and quantity of timber is less than that of stand 2 (conventional) (basal area = 118 ft.^{2}/acre). It is known that factors such as knottiness, stem taper, growth rate, and percentage of juvenile wood should have similar detrimental effects on both lumber and plywood properties. Therefore, the lumber quality of stand 1 (sudden sawlog) is questionable given the plywood results. Further study toward this end is necessary.

The live crown region is the percentage of the total length of the stem that is covered by live branches. This region is critical for both lumber and veneer because wood obtained from this region is knotty and not as strong as defect-free wood. Also, since wood from this region is near the photosynthetically active live crown, its properties are detrimentally influenced more than wood from lower on the bole. The increase in specific gravity from pith to bark is slower and levels out later in the upper bole than in the lower 2 m of the bole (9). Data by Groom and Mullins (6) indicates that all of the veneer from stand 1 (sudden sawlog) came from outside the live crown area. Fifty-six percent of the total tree height of the harvested trees from stand 1 is in the live crown area (**Table 4**). Given our knowledge of the live crown effect on

TABLE 4. — Basic site information mean values of the five harvested loblolly pine trees from the five stands growing near Crossett, Ark.

Stand	Age	Height	DBH[a]	Basal area	Site index	Live crown ratio[b]
	(yr.)	(ft.)	(in.)	(ft. ^{2}/acre)		(%)
1 - Sudden sawlog	48	94.2	21.1	90	95	56
2 - Conventional	48	93.8	15.3	118	95	39
3 - Natural	48	98.6	16.4	76	100	39
4 - Single tree	49	88.6	16.4	72	89	55
5 - Crop tree	79	110.2	24.7	42	97	56

[a] DBH = diameter at breast height.
[b] Live crown ratio = (length of live crown/total length of tree) × 100.

TABLE 5. — MOR and MOE at two moisture levels and four veneer grade arrangements of three-ply loblolly pine plywood.[a]

	Dry condition (40% RH, 110°F)				Wet condition (24-hr. water-soak)				
Layup	MC[b]	SG[c]	MOR	MOE	MC	MOR	MOE	Thickness swell	Width swell
	(%)		(psi)	(× 10^6 psi)	(%)	(psi)	(× 10^6 psi)	(%)	(%)
AAA	7.8	0.69	14,734 A[d]	2.34 A	28.8	5,471 A	1.50 A	11.88 AB	1.65 A
			(0.76)[e]	(0.68)		(0.98)	(0.87)	(1.23)	(1.98)
CCC	7.2	0.66	13,492 B	1.87 C	27.7	4,681 B	1.25 B	12.40 AB	1.68 A
			(0.74)	(0.76)		(0.68)	(0.79)	(0.98)	(1.69)
ACA	7.2	0.69	11,902 A	2.20 AB	26.8	5,092 AB	1.44 A	13.09 A	1.62 A
			(0.98)	(0.76)		(0.94)	(0.67)	(1.23)	(1.12)
ACC	7.7	0.61	10,987 B	2.07 B	29.6	4,822 B	1.31 B	11.61 B	1.54 A
			(0.99)	(0.79)		(0.68)	(0.79)	(1.11)	(1.43)

[a] Each value represents the mean of 96 samples.
[b] Moisture content (%) ovendry basis.
[c] Specific gravity based on volume and weight at 40% RH and 110°F.
[d] Means followed by the same capital letter are not significantly different (Tukey test).
[e] Values in parentheses are coefficients of variation (%).

wood properties, the fact that stand 2 (conventional) outperformed stand 1 (sudden sawlog) is surprising.

The stands displayed a similar pattern for MOE as was shown for MOR. Stand 2 (conventional) (2.39×10^6 psi) was significantly superior to stands 1 (sudden sawlog), 3 (natural regeneration), 4 (single tree selection), and 5 (crop trees) by 11, 12, 12, and 22 percent, respectively. MOE is largely governed by anatomical properties, such as fibril angle, rather than defects, such as knots (7). It was our intention to randomly select veneer from various trees, peeler bolts, and locations within the bolts for each stand for panel fabrication. This would allow the panels from each stand to be more representative of a particular stand and differences between stands to be attributable to the stands rather than bias sampling from specific peeler bolts or zones within a bolt.

Our finding concerning MOE is significant because Shupe et al. (11) also did not observe significant differences in MOE of 13-ply, SYP laminated veneer lumber. That study by Shupe et al. (11) used veneer from the same source as this study and veneer was also selected similarly — based only on veneer grade and stand. It was speculated by the authors that a random veneer selection for a particular stand would consequently contain veneer of various fibril angles, and detection of significant MOE differences between stands for LVL would be hindered by the inherent variation of anatomical properties within the stands, which largely govern MOE.

BENDING PROPERTIES: VENEER GRADE LAYUP EFFECTS

With regard to veneer grade placement in a panel, our results indicate that MOR is highest for the dry samples when A-grade veneers are on both faces of the panel (**Table 5**). There was no significant difference for MOR between AAA (14,734 psi) and ACA (11,902 psi). As with MOR, there was no significant difference in MOE between AAA (2.34×10^6 psi) and ACA (2.20×10^6 psi). However, contrary to the MOR findings, the difference in MOE between ACA and ACC was not significant. ACA did not significantly differ from ACC (2.07×10^6 psi).

The effect of MC on mechanical properties of plywood is shown in **Table 5**. The following pattern was displayed by the stands for bending MOR and MOE determination in the wet condition: AAA > ACA > ACC > CCC. This pattern held consistent for most, but not all, of the stands. In short, as the number of A grade veneer in the panel decreases, bending properties will diminish. The AAA group was 8, 19, and 25 percent greater in MOR than CCC, ACA, and ACC, respectively. Similarly, AAA was 6, 12, and 20 percent greater in MOE than CCC, ACA, and ACC, respectively.

It is interesting to note that the MOR reduction in the wet condition for the four different veneer grade arrangements ranged from 60 to 63 percent, and the MOE reduction was much less (33% to 37%). It has previously been shown that of the elastic constants, Young's modulus along the grain is the least sensitive to MC (7).

SHEAR STRENGTH

Table 6 indicates little difference in mean shear strength between the stands for a particular shear test treatment. In general, the vacuum-soak specimens showed the highest mean shear strength retention and the boiled specimens had the lowest. The percentage of wood failure was not affected by the type of shear test performed or the stand effect.

TABLE 6. — Effect of silvicultural practice on loblolly pine plywood shear strength and percentage of wood failure as determined by three test treatments.[a]

Stand[b]	Vacuum-soak	Vacuum-pressure	Boil-dry-boil
	(psi)		
1	272.7	243.7	232.2
	(66.3)[c]	(66.8)	(70.6)
2	266.9	250.4	236.2
	(72.4)	(77.8)	(72.5)
3	262.5	269.4	246.3
	(67.9)	(62.9)	(65.7)
4	274.5	278.7	243.0
	(77.9)	(77.1)	(74.9)
5	273.4	286.8	248.8
	(76.6)	(75.6)	(76.0)

[a] Each value represents the mean of 130 samples. No significant differences by the Tukey test were observed between the stands regarding shear strength or wood failure for a particular treatment.
[b] Stand 1 = sudden sawlog; stand 2 = conventional; stand 3 = natural regeneration; stand 4 = single tree selection; stand 5 = crop trees.
[c] Values in parentheses are wood failure (%).

The effect of different veneer layup patterns on shear strength retention appears to be minimal. The highest shear strength was obtained with AAA. The other three layups showed very little difference in mean shear strength retention. The AAA panels yielded the most favorable results because of the different processing of A- and C-grade veneer. These tests were done on clear specimens, but clear wood from C-grade veneer has a high frequency of knots in the full-size 54- by 98-inch sheets.

TABLE 7. — Effect of four different veneer layup patterns and three test treatments on loblolly pine plywood shear strength and wood failure.[a]

Layup	Vacuum-soak	Vacuum-pressure	Boil-dry-boil
	(psi)		
AAA	291.83	286.04	246.98
	(65.81)[b]	(70.72)	(68.93)
CCC	266.26	263.47	234.03
	(73.13)	(75.49)	(75.61)
ACA	263.22	251.14	241.84
	(81.03)	(76.86)	(76.86)
ACC	260.59	264.40	245.26
	(69.00)	(68.10)	(68.55)

[a] Each value represents the mean of 162 samples. No significant differences by the Tukey test were observed regarding shear strength or wood failure between the layups for a particular treatment.
[b] Values in parentheses are wood failure (%).

It is interesting to note that similar shear properties can be obtained with a single A-grade veneer on one face (ACC) as compared to A-grade veneer on both faces (ACA) (**Table 7**). In fact, the ACC panels gave slightly higher mean shear strengths for two (vacuum-pressure and boil) of the three treatments.

CONCLUSIONS

Based upon this research, it appears that three-ply, southern pine plywood bending and shear properties are significantly affected by silvicultural practices. The arrangement of the veneer grades within the panel greatly affects bending properties. Plywood manufactured with all A-grade veneer gave the most favorable results for mechanical properties. Plywood with one A-grade veneer on one face (ACC) showed similar mechanical properties as plywood with A-grade veneer on both faces (ACA).

Since bending and shear properties are similar between ACA and ACC, a possible financial gain may be achieved by placing an A-grade veneer on only one

face of the panel, instead of both faces. Further research on other mechanical and physical properties is recommended to better determine the magnitude of any financial gain.

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