PROPERTIES OF SHEATHING-GRADE PLYWOOD MADE FROM SWEETGUM AND SOUTHERN PINE[1]

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ABSTRACT

Experimental test results of physical and certain important mechanical properties of commercial CDX southern pine plywood, of all-sweetgum plywood, and of plywood with southern pine faces and sweetgum cores are presented. Experimental results indicate that the mechanical properties of all-sweetgum CDX plywood are better than properties of all-southern-pine CDX plywood. Physical properties of all-sweetgum plywood are approximately equal to those of all-southern-pine plywood. In general, the results suggest that all-sweetgum plywood, bonded with phenolic resin, can perform structurally as good as CDX all-southern-pine plywood sheathing in house construction.

It is recommended that the American Plywood Association undertake tests according to their performance based standards on all-sweetgum plywood panels to verify and certify that such panels meet the criteria of APA rated sheathing and APA rated sturd-I-floor programs.

Keywords: Plywood, sheathing, sweetgum, southern pine, structural properties.

INTRODUCTION

Approximately 40% of United States softwood plywood is manufactured from southern yellow pine. Although growth yield of southern yellow pines is able to satisfy present demands for pulp and paper, lumber and plywood, the average diameter of harvested southern pine trees is decreasing (Am. Plywood Assoc. 1981). When current economic conditions improve and house construction reaches levels to satisfy needs, demand for plywood sheathing will surpass current production levels by 3 to 4 billion sq ft (3/8-inch basis) per year (Am. Plywood Assoc. 1981). Part of this additional plywood for sheathing may be manufactured either entirely from sweetgum (*Liquidambar Styraciflua*) or a combination of southern pine and hardwood.

The growing stock (9 inches and above in diameter) of all hardwoods in the South (104.3 billion cubic ft) represents 52% of the total Southern forests (USDA 1978). Sweetgum represents 12% of all growing hardwood stock in the South (USDA 1978). Density, gluability, strength, and physical properties of sweetgum

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are comparable to those of loblolly pine (*Pinus taeda*) (USDA 1974). Sweetgum peels easily into veneer and produces relatively smooth veneer surfaces.

This paper compares the physical and mechanical properties of commercially produced CDX southern pine plywood with those of sweetgum plywood and plywood made from southern pine veneer faces and sweetgum core.

MATERIALS

Five commercial CDX southern yellow pine plywood panels (4 ft × 8 ft) were randomly selected in a plywood mill from each of the following three constructions: 3-ply, ½ inch; 4-ply, ½ inch; and 5-ply, ⅝ inch. All veneers of 4-ply and 5-ply were ⅛ inch thick, while all veneers of the 3-ply were $^1/_6$ inch thick. In addition, the following experimental plywood panels were constructed in the same mill: five panels 4-ply, ½ inch with all-sweetgum[2] C faces, D backs, and C-D cores; five panels 4-ply, ½ inch with southern pine C faces, D backs, and sweetgum C-D cores; five panels 5-ply, ⅝ inch with southern pine C faces, D backs, and sweetgum C-D crossbands and center. All veneers were rotary cut and were ⅛ inch thick.

All CDX southern pine and sweetgum plywood panels were fabricated with a commercial extended phenolic resin with a spread of 90 lb per 1,000 sq ft of double glueline. All panels were prepressed at room temperature with 160 psi for approximately 3 min, then hot-pressed with 200 psi at 305 F for 3.5 min for 3-ply, ½ inch; 4 min for 4-ply, ½ inch; and 5 min for 5-ply, ⅝ inch.

TESTING

Three of the five panels of each of the six plywood groups were randomly selected to obtain specimens for evaluating the following properties:

1) Flexure. Twelve specimens, with the grain of face veneers parallel to the span, from each of the six groups were tested to failure in each of three moisture conditions. A total of 216 specimens (12 replications for each of the six groups under three conditions) were tested to failure with central loading at speeds according to ASTM D3043 (1974). The three test conditions were as follows: original (65% RH and 72 F); water-soaked (48 h); and cycled (soaked and reconditioned at 65% RH and 72 F). Specimen dimensions were 6 inches × 26 inches (24 inches clear span) for ½ inch thickness and 6 inches × 32 inches (30 inches clear span) for ⅝ inch thickness. Matching of specimens in the three test conditions was obtained by consequently assigning each adjacent specimen to one of the three conditions in sequence and repeating.
2) Edgewise shear strength (rail shear). Twelve specimens, 3.5 inches × 10 inches from each of the six plywood groups were tested at each moisture condition. A total of 216 specimens (12 replications for each of the six groups under three conditions) were tested according to ASTM D1037 (1974).
3) Plate shear modulus. Six specimens from each plywood group were tested at each moisture condition. The ½-inch-thick specimens were 16 inches × 16

[2] All-sweetgum veneers were better (either smaller size knots or lower frequency) than veneer of southern yellow pine.

inches, while the ⅝-inch-thick were 20 inches × 20 inches. Testing was performed according to ASTM D3044 (1974).

4) Glueline shear strength. Twelve specimens, 3¼ inches × 1 inch from each of the six plywood groups, were tested at each moisture condition. A total of 216 specimens (12 replications for each of the six groups under three conditions) were tested according to ASTM D906 (1974) for the 3-ply specimens and according to U.S. Product Standard PS-1-66 (1966) for the 4-ply and 5-ply specimens.
5) Dimensional changes with change in moisture content. The six specimens used for determining plate shear modulus were also used for measuring dimensional changes and for water absorption. Changes in specimen thickness, width (perpendicular-to-face veneer grain), length (parallel-to-face veneer grain), and water absorption were measured from the original condition (65% RH, 72 F) to the 48-h soaked condition and again when reconditioned back to the original (65% RH, 72 F) condition.

RESULTS AND DISCUSSION

Flexural properties of the six plywood groups are presented in Table 1. Among the three all-southern-pine plywood constructions (3-ply, 4-ply, and 5-ply), average MOE and MOR values in the original condition of the 3-ply construction were 12% and 9.5% higher than corresponding values of the 4-ply construction, respectively. Furthermore, MOE and MOR values of the 4-ply construction were 22% and 27% higher than corresponding values of the 5-ply construction, respectively. These findings, in general, are in agreement with flexure theory and with experimental results on clear southern pine plywood (Biblis et al. 1972).

Wet-dry cycled specimens retained between 86% and 99% of their original MOE values and between 72% and 86% of their original MOR values. Properties of specimens after 48-h soaking were between 63% and 70% of their original MOE and between 48% and 76% of their original MOR values.

Comparing the flexural properties in the original dry condition of all pine CDX plywood with published clear southern pine plywood properties (Biblis et al. 1972; Chiu and Biblis 1973) of equal thickness and similar construction, we note that flexural properties of clear plywood were 34% to 60% stiffer (MOE) and 60% to 75% stronger (MOR).

Flexural properties of 4-ply, ½ inch all-sweetgum plywood in the original dry condition were 20% higher in MOE and 53% higher in MOR than corresponding values of 4-ply, ½ inch all-southern-pine CDX plywood. This might be due to the fact that the sweetgum veneers were of somewhat better quality than the pine veneers. Flexural properties of plywood ⅝ inch thick with southern pine faces and sweetgum cores in the original condition were stiffer (30% higher MOE) and stronger (60% higher MOR) than equal thickness all-pine plywood. The ½ inch-thick two-species plywood was less stiff (25% lower MOE) and weaker (27% lower MOR) than the all-southern-pine plywood. This suggests that flexural properties are influenced more by quality of the face veneer rather than by the core species.

Shear properties of the six plywood groups are presented in Table 2. The plate shear modulus in the original dry condition of the all-southern-pine plywood panels was 62,000 psi for 3-ply and 82,000 psi for 4-ply. The value of all-sweetgum

TABLE 1. *Flexural properties of commercial CDX plywood with all veneer plies (a) southern pine, (b) sweetgum, and (c) southern pine faces and sweetgum crossbands.*[1]

Face and core species	Panel thickness	No. of plies	M.C. %	Density (o.d.b.)	Moisture condition	MOE (10^3 psi)	Flexure parallel[2] FSPL (psi)	Flexure parallel[2] MOR (psi)
All veneers	½"	3	10.1	0.53	Original	1,450 (215)[3]	3,990 (774)	7,170 (2,220)
s. pine			60.3		Soaked	913 (221)	2,400 (1,150)	3,860 (935)
			13.1		Cycled[4]	1,339 (347)	3,620 (814)	5,504 (1,439)
All veneers	½"	4	9.8	0.61	Original	1,295 (208)	4,225 (1,397)	6,550 (1,690)
s. pine			60.0		Soaked	912 (130)	2,155 (597)	4,480 (797)
			13.0		Cycled	1,283 (164)	3,960 (1,059)	6,790 (1,458)
Faces: s. pine	½"	4	10.1	0.55	Original	1,035 (148)	3,045 (1,450)	5,170 (2,353)
Core:			67.3		Soaked	650 (223)	1,770 (580)	2,855 (1,070)
sweetgum			13.7		Cycled	907 (222)	2,740 (1,131)	4,450 (1,710)
All veneers	½"	4	10.0	0.59	Original	1,554 (78)	5,665 (826)	10,030 (550)
sweetgum			64.7		Soaked	1,047 (164)	2,575 (396)	4,850 (601)
			13.5		Cycled	1,341 (83)	3,763 (627)	7,230 (674)
All veneers	⅝"	5	9.8	0.58	Original	1,059 (323)	2,695 (1,637)	5,200 (2,470)
s. pine			50.0		Soaked	745 (222)	1,390 (490)	3,970 (1,990)
			13.6		Cycled	963 (325)	2,690 (1,206)	4,140 (1,803)
Faces: s. pine	⅝"	5	10.4	0.56	Original	1,373 (333)	5,365 (1,394)	8,390 (1,586)
Core and cross-								
bands:			63.5		Soaked	1,261 (356)	2,515 (553)	4,630 (666)
sweetgum			14.3		Cycled	1,288 (268)	3,916 (1,150)	7,340 (1,431)

[1] Each value represents the mean of twelve specimens. Property values of soaked and cycled specimens were based on dimensions at time of test.

[2] Specimens were 6 inches wide, ½ inch tested over 24-inch span, ⅝ inch tested over 30-inch span, with veneer grain orientation along the span.

[3] Values in parentheses represent standard deviations.

[4] Specimens were first water soaked for 48 h, then conditioned to equilibrium at 65% R.H., 72 F and then tested.

4-ply plywood in the same condition was 87,000 psi. Plate shear modulus of plywood with southern pine faces and sweetgum cores in the original condition was 8% greater for ⅝ inch-thick plywood and 11% lower for ½ inch-thick plywood than all-southern-pine plywood of equal thickness. This suggests that the quality of all veneers has greater influence than veneer species. The values of plate shear modulus of wet-dry cycled plywoods were between 76% and 84% of corresponding values at the original dry condition. Values of plate shear modulus of 48-h soaked plywoods were between 63% and 73% of their values at the original dry condition.

The rail shear strength of all-pine plywood in the original dry condition varied between 660 psi (3-ply) and 970 psi (4-ply), while the corresponding value of all-sweetgum plywood was 1,000 psi (4-ply). The rail shear strength of plywood with southern pine faces and sweetgum cores in the original condition was 6% higher for ⅝ inch-thick plywood and 18% lower for ½ inch thickness than the all-southern-pine plywood of equal thickness. This suggests that the quality of all veneers has greater influence than veneer species. Wet-dry cycled plywoods retained between 71% to 80% of their original rail shear strength, while rail shear values of 48-h soaked plywoods were between 56% to 60% of their original values. The

TABLE 2. *Shear properties of commercial CDX plywood with all veneer plies (a) southern pine, (b) sweetgum, and (c) southern pine faces and sweetgum core and crossbands.*[1]

Face and core species	Panel thickness	No. of plies	M.C. %	Density (o.d.b.)	Moisture condition	Plate shear G (103, psi)	Rail shear strength (psi)	Glueline	
								Shear strength (psi)	Wood failure (%)
All veneers	½"	3	10.1	0.53	Original	61.7 (6.7)[2]	660 (67)	190 (41)	70 (36)
s. pine			60.3		Soaked	42.9 (8.4)	370 (34)	90 (26)	65 (32)
			13.1		Cycled[3]	48.3 (3.5)	510 (94)	140 (47)	60 (32)
All veneers	½"	4	9.8	0.61	Original	81.6 (8.0)	970 (53)	240 (32)	85 (17)
s. pine			60.0		Soaked	56.6 (6.5)	570 (45)	190 (40)	80 (16)
			13.0		Cycled	65.3 (7.3)	780 (59)	140 (35)	80 (19)
Faces: s. pine	½"	4	10.1	0.55	Original	73.8 (3.9)	820 (83)	240 (66)	95 (9)
Core:			67.3		Soaked	49.4 (5.2)	470 (35)	150 (47)	90 (13)
sweetgum			13.7		Cycled	56.0 (2.7)	620 (51)	200 (58)	95 (17)
All veneers	½"	4	10.0	0.59	Original	87.0 (6.6)	1,000 (105)	220 (42)	90 (23)
sweetgum			64.7		Soaked	54.4 (2.8)	600 (39)	115 (23)	90 (13)
			13.5		Cycled	66.2 (4.9)	710 (46)	170 (48)	80 (26)
All veneers	⅝"	5	9.8	0.58	Original	76.1 (5.3)	900 (55)	255 (40)	85 (18)
s. pine			50.0		Soaked	54.1 (5.9)	500 (55)	150 (34)	80 (15)
			13.6		Cycled	63.6 (4.8)	710 (66)	225 (50)	80 (25)
Faces: s. pine	⅝"	5	10.4	0.56	Original	82.0 (3.6)	950 (88)	225 (39)	95 (3)
Core and cross-									
bands:			63.5		Soaked	60.1 (4.3)	550 (60)	110 (20)	90 (10)
sweetgum			14.3		Cycled	67.4 (3.8)	750 (57)	180 (29)	98 (3)

[1] Each value represents the mean of twelve specimens except plate shear, which is the average of six specimens. Property values of soaked and cycled specimens were based on dimensions at time of test.
[2] Values in parentheses represent standard deviation.
[3] Specimens were first water soaked for 48 h, then conditioned to equilibrium at 65% R.H., 72 F and then tested.

glueline shear strength of all-pine plywood in the original dry condition was between 190 psi (3-ply) and 240 psi (4-ply), with 70% to 85% wood failure, while the corresponding value of all-sweetgum (4-ply) plywood was 220 psi with 90% wood failure. Specimens of wet-dry cycled plywood retained between 58% and 88% of their original glueline shear strength. The 48-h soaked specimens retained between 47% and 79% of their original glueline shear strength.

Dimensional changes with moisture are presented in Table 3. Thickness swelling of all plywoods from 65% RH to 48-h soaking was between 6.9% to 9.2%. The corresponding value of all-sweetgum plywood was 7.8%. The residual thickness swelling of wet-dry cycled all-pine plywoods varied from 2.8% to 5.7%; the corresponding value of all-sweetgum plywood was 3.3%. The linear swelling of all plywoods from 65% RH to 48-h soak along the grain of face veneers varied from 0.10% to 0.29%, while in the direction perpendicular-to-face grain varied from 0.27% to 0.33%. The water absorption from 65% RH to 48-h soak of all plywoods varied from 36.7% to 51.6%.

SUMMARY

Experimental test results of physical and certain important mechanical properties of commercial CDX southern pine plywood, of all-sweetgum plywood, and

TABLE 3. *Dimensional changes of commercial CDX plywood with all veneer plies (a) southern pine, (b) sweetgum, and (c) southern pine faces and sweetgum core and crossbands.*[1]

Face and core species	Panel thickness	No. of plies	Density (o.d.b.)	Original M.C. at 65% RH	Moisture condition	Swelling (%)				Water absorption
						M.C. (%)	Thickness	Length	Width	
All veneers	½″	3	0.52	9.9	From 65% RH to 48-h soak	60.3 (2.4)[2]	9.20 (2.44)	0.13 (0.11)	0.27 (0.08)	45.9 (2.3)
s. pine					Cycled[3]	13.1 (0.1)	5.01 (2.44)	0.04 (0.02)	0.08 (0.01)	2.9 (0.1)
All veneers	½″	4	0.60	9.1	From 65% RH to 48-h soak	52.7 (5.2)	9.19 (0.54)	0.24 (0.04)	0.27 (0.05)	39.9 (4.5)
s. pine					Cycled	12.7 (0.2)	5.74 (0.65)	0.07 (0.02)	0.06 (0.03)	3.2 (0.1)
Faces: s. pine Core:	½″	4	0.55	10.4	From 65% RH to 48-h soak	67.3 (5.1)	7.40 (0.49)	0.26 (0.10)	0.35 (0.07)	51.5 (4.6)
sweetgum					Cycled	13.7 (0.3)	3.18 (0.27)	0.01 (0.01)	0.07 (0.01)	2.9 (0.4)
All veneers	½″	4	0.58	8.6	From 65% RH to 48-h soak	64.7 (1.8)	7.84 (0.36)	0.29 (0.07)	0.32 (0.05)	51.6 (1.8)
sweetgum					Cycled	13.5 (0.3)	3.32 (0.27)	0.05 (0.02)	0.06 (0.01)	4.5 (0.4)
All veneers	⅝″	5	0.58	9.3	From 65% RH to 48-h soak	49.5 (1.4)	7.44 (0.88)	0.10 (0.03)	0.33 (0.11)	36.7 (1.3)
s. pine					Cycled	13.6 (0.3)	3.28 (0.75)	0.03 (0.01)	0.06 (0.02)	3.9 (0.4)
Faces: s. pine Core & crossbands:	⅝″	5	0.56	9.9	From 65% RH to 48-h soak	63.5 (4.5)	6.93 (0.57)	0.15 (0.04)	0.32 (0.07)	48.7 (4.4)
sweetgum					Cycled	14.3 (0.3)	2.83 (0.43)	0.04 (0.01)	0.08 (0.03)	3.9 (0.1)

[1] Each value respresents the mean of six specimens.
[2] Values in parentheses represent standard deviations.
[3] Specimens were first conditioned to 65% R.H., 72 F and measured, then soaked for 48 h and measured, and finally reconditioned to 65% R.H., 72 F and measured.

of plywood with southern pine faces and sweetgum cores are presented. Experimental results indicate that the mechanical properties of all-sweetgum CDX plywood are better than properties of all-southern-pine CDX plywood. Results also indicate that properties of plywood with southern pine veneer faces and sweetgum cores were higher than those of all-pine plywood in one thickness (⅝ inch) and lower in another (½ inch). Physical properties of all-sweetgum plywood are approximately equal to those of all-southern-pine plywood.

In general, the results suggest that all-sweetgum plywood, bonded with phenolic resin, can perform structurally as well as CDX all-southern-pine plywood sheathing in house construction.

As expected, the 3-ply all pine ½-inch plywood was approximately 16% stiffer and stronger in flexure parallel-to-face grain than 4-ply all-pine ½-inch plywood of equal veneer quality. Wet-dry cycled specimens retained in flexure at least 86% of the original MOR values. Flexure specimens tested after 48-h soak retained between 63% to 70% of their original stiffness and between 48% and 76% of their original strength.

It is strongly recommended that the American Plywood Association undertake tests according to their performance based standards on all-sweetgum plywood panels to verify and certify that such panels meet the criteria of APA rated sheathing and APA rated sturd-I-floor programs.

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