Holzforschung
53 (1999) 215–222

Effect of Silvicultural Practice and Wood Type on Loblolly Pine Particleboard and Medium Density Fiberboard Properties

By Todd F. Shupe[1], Chung Y. Hse[2], Elvin T. Choong[3], and Leslie H. Groom[2]

[1] Louisiana Cooperative Extension Service, Louisiana State University Agricultural Center, Baton Rouge. LA, USA
[2] USDA Forest Service, Southern Research Station, Pineville, LA, USA
[3] School of Forestry, Wildlife. and Fisheries. Louisiana State University Agricultural Center, Baton Rouge, LA, USA

Fiberboard
Innerwood
Internal bond
Loblolly pine
Modulus of elasticity
Modulus of rupture
Outerwood
Particleboard

Summary

The objective of this study was to determine the effect of five different silvicultural strategies and wood type on mechanical and physical properties of loblolly pine (*Pinus taeda* L.) particleboard and fiberboard. The furnish was prepared in an unconventional manner from innerwood and outerwood veneer for each stand. Modulus of rupture (MOR) differences between the stands were insignificant for particleboard. Some significant modulus of elastisity (MOE) differences existed between the stands for particleboard and fiberboard. Differences between the wood types were minimal for each stand. Innerwood yielded higher mean MOR, MOE, and internal bond (IB) values than outerwood for most of the stands. The differences between the stand and wood types for 2 and 24 h thickness swell and 2 and 24h water adsorption were very minimal. This research has shown that innerwood can produce particleboard and fiberboard panels with very comparable mechanical and physical properties to outerwood. The effect of the silvicultural strategy (i.e., stand) was minimal for most properties.

Introduction

The literature is voluminous in describing the effects of silvicultural practice on anatomical, mechanical. chemical, and physical properties of southern pine wood. Numerous studies have shown the detrimental effect of juvenile wood on lumber, paper, and plywood. The current state of knowledge relating pine heartwood furnish and binders for particleboard has been summarized by Dix and Roffael (1997 a). A series of investigations has addressed the gluability of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) heartwood and sapwood (Lelis *et* al. 1994a, 1994b; Lelis and Roffael 1995). However, little research has been conducted to evaluate the effect of silvicultural practice on particleboard or fiberboard.

As the demand for wood continues to increase, the production of wood-based composites will likely increase. Particleboard and fiberboard are two wood-based composites that can be produced from trees much too small for lumber. Pugel et *al.* (1989a, 1989 b) conducted studies on composites from. southern pine juvenile wood and believed the effect of juvenile wood on composites should be evaluated not only in terms of problems but in terms of the potential for using this type of furnish to produce economical, effective, and possibly, new products. Also, regardless if juvenile wood helps or hinders the performance of composites, more of it is being used in composites through the harvesting of fast-grown trees and whole-tree utilization. The studies by Pugel et *al.* (1989a, 1989b) are some of the few studies that have investigated the effect of juvenile wood on particle-based composites such as particleboard or fiberboard. Dix and Roffael produced particleboard from heartwood and sapwood from larch (*Larix decidua* Mill.) (Dix and Roffael 1995) and Scots pine (*Pinus sylvestris* L.) (Dix and Roffaei 1997 b). Both studies showed that the strength properties of heart-wood and sapwood boards were found to deteriorate with increasing tree age. Also, heartwood boards yielded more favorable physical property results (Dix and Roffael 1995, 1997 b).

This study does not attempt to directly determine the effect of juvenile wood on southern pine particleboard or fiberboard. Instead our research was designed to address the increase in plantation-grown Southern yellow pine (SYP) wood by sampling five silviculturally different stands. Furthermore, we selected innerwood and outerwood from each of the five stands to determine the extent of wood type differences between and among the stands. The objectives of this study were to determine the effect of (i) silvicultural strategy and (ii) wood type (innerwood or juvenile wood and outerwood or mature wood) on the mechanical and physical properties of loblolly pine particleboard and fiberboard.

Methods

Furnish preparation

Five representative trees each from five silviculturally different loblolly pine (*Pinus taeda* L.) stands growing near Crossett, AR were harvested and bucked into peeler bolts. All stands are described in detail by Baker and Bishop (1986) and Shupe et al. (1997). Three of the silvicultural regimes were even-aged and consisted of stand 1 (sudden sawlog), stand 2 (conventional), and stand 3 (natural regeneration). The sudden sawlog and conventional stands were the only true plantations included in the study. The uneven-aged stand investigated was subdivided into two tree age classes, i.e. stand 4 (single tree selection) and stand 5 (crop trees).

This study was done in conjunction with other veneer-based studies. Consequently, the bolts were rotary-peeled and clipped by Hunt Plywood at Pollock, LA to approximately 137 cm x 249 cm at a target thickness of 0.3175 cm. The veneer was coded according to stand, tree number, and bolt number as it was peeled. The veneer was dried commercially to a moisture content (MC) of 6-8 %, transported to the USDA - Forest Service, Southern Research Station in Pineville, LA, stored in a controlled environment of 22°C and 36 % relative humidity (RH), and graded by an APA - The Engineered Wood Association veneer grader.

Veneer sampling was limited to the bottom two peeler bolts for all stands. Innerwood was considered the last ten veneer sheets removed from a peeler bolt, and outerwood was treated as the first ten sheets peeled from a bolt. All bolts were peeled to a final diameter of 7.62 cm. Therefore, our innerwood was considered to be entirely juvenile wood and heartwood, and the outerwood was clearly in the sapwood zone.

The selected veneers were passed through a standard lawn and garden chipper and then subjected to steam for 1 hour. This material was then ground to particle size in a laboratory disk refiner. The refiner was adjusted to a narrower clearance and water was injected to reduce particles to fibers. Excess water from the fiber slurry was removed *via* a laboratory vacuum. Fiber was then dried at 27°C for 24h. Before spraying, fiber bundles were separated in the spray drum by the beating action of a propeller in the bottom of a 189 l drum. Urea formaldehyde resin especially formulated for particleboard and fiberboard was obtained from Borden's Co. Alexandria, LA, USA, and was used for both particleboard and fiberboard fabrication.

Due to laboratory limitations, the methods used to manufacture particleboard and fiberboard are not truly representative of those commonly used in industry today. However, since the resin formulation, resin application, and hot-press schedule was similar, differences observed between groups can be definitively attributed to the inherent differences in the wood rather than the processing techniques employed.

Particleboard manufacture

Particles containing a furnish MC of 2.8% were sprayed with a urea formaldehyde (UF) resin (65 % solids). Resin was applied at the rate of 6 % solids based on the ovendry weight of the wood particles in a 189 l drum equipped with air-injection to keep the particles in suspension and optimize resin distribution. No wax was applied. The same drum blender and resin sprayer was used to prepare each mat. The drum blender was carefully cleaned between groups to avoid cross contamination. Panels were manufactured at a target density of 720 kg/m^3. Two panels were pressed simultaneously with each press cycle. All particleboard panel types were replicated four times. Mats were hand-felted and randomly oriented in a forming box for a target thickness of 1cm. The press schedule was 30 seconds to stops, reduction of initial pressure after 2 minutes, and gradual relief of pressure during the last minute of the 5 minute press cycle. The platen temperature was 221°C. The press schedule was developed in accordance with recommendations by Borden's technical representatives. The resulting panels were 1cm by 56 by 81 cm. Panels were stacked on edge for 24-hours at 22°C and 36% RH prior to cutting test specimens.

Fiberboard manufacture

Fibers containing a furnish MC of 2.9 % were sprayed with a urea formaldehyde (UF) resin (65 % solids). Resin was applied using a laboratory-scale blade separator/blender, previously reported by Liang *et al.* (1994), at the rate of 6 % solids based on the ovendry weight of the wood particles. No wax was applied. The same drum blender and resin sprayer was used to prepare each mat. Borden Co. supplied UF resin that was especially formulated for particleboard and fiberboard. The same resin was used for both panel types. The drum blender was carefully cleaned between groups to avoid cross contamination. Resin was applied in a 189 l drum equipped with air-injection to keep the fibers in suspension and optimize resin distribution. Panels were manufactured at a target density of 704 kg/m^3. One panel was pressed for each press cycle. All fiberboard panel types were replicated four times. Mats were hand-felted and randomly oriented in a forming box for a target thickness of 1cm. The press schedule was 30 seconds to stops, reduction of initial pressure after 2 minutes, and gradual relief of pressure during the last minute of the 5-minute press cycle. The platen temperature was 221 °C. The press schedule was developed in accordance with recommendations by industry technical representatives. The resulting panels were 1 cm by 56 by 81 cm. Panels were stacked on edge for 24-hours prior to cutting test specimens at 22 °C and 36 % RH.

Testing

Particle and fiber size distributions were determined on a Bauer-McNett screen system. Five samples of each group, weighing 100 g each, were processed and their results averaged. All the size classifications were conducted on airdry material.

For particleboard and fiberboard three static bending specimens (7.6 x 43.2 cm) were selected from each of the four panel replications (12 bending specimens for each combination of stand and wood type). All specimens were stored on stickers for 4 weeks at 22°C and 36% RH. The procedures for determination of modulus of elasticity (MOE), modulus of rupture (MOR), and internal bond (IB) as prescribed by ASTM D 1037-93 (ASTM 1993a) were followed. Four IB specimens and one MC-density specimen were cut from undamaged portions of all the failed bending specimens. Swelling was determined on a 2 and 24 h. basis as a percentage of dimension increase from the original dry dimensions, and water adsorption was determined as the percentage of weight gain from the original dry dimensions after 2 and 24h water submersion. Two 15.24 cm^2 samples were cut from each panel for thickness swell and water adsorption determinations in accordance with ASTM D 1037-94 (1993a). Water soak properties were measured, even though a sizing agent was not used, to determine the magnitude of inherent physical property differences between the different stands and wood types. The software package used in conjunction with the Instron testing machine allowed for data to be downloaded and analyzed using a factorial analysis on SAS (1989). Tukey's Honest Significant Difference test was employed to determine significance between means.

Results and Discussion

Particle and fiber size analysis

The analysis of particle and fiber sizes is presented in Table 1. The refining process produced similar size distributions between the stands for the particles and fibers. Moreover, the size analysis showed minimal differences between innerwood and outerwood. Since the size differences within the particle and fiber category were small, we assumed that this factor did not influence the panel properties of particleboard or fiberboard, respectively, appreciably for any stand or wood type.

The particle and fiber sizes were analyzed using the same set of screens to illustrate the differences these two particle types. Therefore, the fibers had low retention on the No. 8

Table 1. Particle and fiber size analysis of loblolly pine wood composites furnishes

	Stand[1]									
	1		2		3		4		5	
Particles(%)[2]	Inner[3]	Outer[3]	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
No. 8	0.72	0.47	0.82	0.68	3.14	0.49	0.79	0.48	0.30	0.35
No. 10	1.67	1.35	2.53	3.19	7.79	1.68	2.58	2.22	2.15	2.26
No. 20	65.71	67.26	70.47	73.63	68.46	70.83	72.23	72.38	77.55	69.72
No. 40	[illegible].21	31.66	20.36	17.48	15.00	19.79	17.19	17.71	15.82	20.16
No. 60										
4.64	4.76	3.13	2.84	2.60	3.91	3.65	3.35	1.89	4.02	
P-60	5.04	4.50	2.68	2.19	3.02	3.31	3.57	3.86	2.29	3.49
Fibers(%)[2]										
No. 8	3.02	2.01	1.02	2.65	3.68	3.00	3.02	2.00	2.32	2.03
No. 10	5.03	4.32	6.32	4.63	4.12	4.11	5.00	4.32	4.85	5.02
No. 20	10.51	9.62	11.36	8.63	9.63	11.12	10.65	8.96	9.68	10.52
No. 40	26.68	29.21	28.65	27.56	25.63	25.64	26.98	27.25	27.00	27.56
No. 60	26.51	27.53	25.32	26.67	27.89	26.98	27.82	29.63	26.32	27.63
P-60	28.25	27.59	27.33	29.98	29.00	29.00	27.89	28.11	29.99	28.25

[1] Stand 1 = Sudden sawlog. Stand 2 = Conventional. Stand 3 = Natural regeneration. Stand 4 = Single tree selection. Stand 5 = Crop trees. [2] Percentage of material retained on Bauer-McNett screen sizes. P-60 denotes material passing through the No. 60 size screen. [3] Inner = Innerwood, Outer = Outerwood.

Table 2. Loblolly pine wood panel densities and compaction ratios

	Stand[1]									
	1		2		3		4		5	
	Inner[2]	Outer[2]	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Veneer Density[3]	28.75	34.38	29.54	34.57	27.56	33.88	28.69	34.51	29.02	34.07
Particleboard (720 kg/m³)										
Moisture content[4]	6.0	6.0	5.9	6.1	6.6	6.4	7.5	7.6	1.6	7.5
Panel density (kg/m³)[3]	668	676	674	660	65.5	694	673	671	679	660
Compaction ratio	1.44	1.23	1.43	1.19	1.48	1.28	1.46	1.21	1.46	1.21
Fiberboard (704 kg/m³)										
Moisture content[4]	6.3	6.5	6.5	6.3	6.1	6.1	6.5	6.6	6.6	6.5
Panel density (kg/m³)[3]	660	641	628	641	652	695	612	644	663	638
Compaction ratio	1.43	1.16	1.22	1.16	1.48	1.28	1.33	1.16	1.43	1.16

[1] Stand 1 = Sudden sawlog. Stand 2 = Conventional. Stand 3 = Natural regeneration. Stand 4 = Single tree selection. Stand 5 = Cr op trees. [2] Inner = Innerwood, Outer = Outerwood. [3] Density values were obtained in accordance with ASTM D 2395-83 (volume by measurement) (ASTM 1993 b). [4] Moisture content based on ovendry conditions after specimens were conditioned on stickers for four weeks at 22°C and 36 % RH.

screen and a high proportion passing the No. 60 screen. We emphasize that our results were obtained using laboratory produced furnishes that were intended mainly to determine the effect of silvicultural strategy and wood type on basic mechanical and physical properties. These furnishes are not necessarily representative of current commercial furnishes.

Panel densities and compaction ratio

The density of the veneer used to produce the furnishes, density and MC of the panels, and compaction ratios are presented in Table 2. The panel densities did not greatly differ between the stands or wood types for either panel type. It was therefore assumed that panel density was not significant in interpreting mechanical or physical property differences between the stands or wood types for either panel type.

The target densities of 720 and 704 kg/m³ were not met for the particleboard or fiberboard panels, respectively. The densities were lower by 32 to 64 kg/m³ for the particleboard panels and 16 to 80 kg/m³ for the fiberboard panels. These lower densities were expected due to the tendency of mats to spread during press closure (Pugel et *al.* 1989a). Our density values are acceptable because although the target densities were not achieved the densities that were obtained do not greatly differ between the stands or wood types and

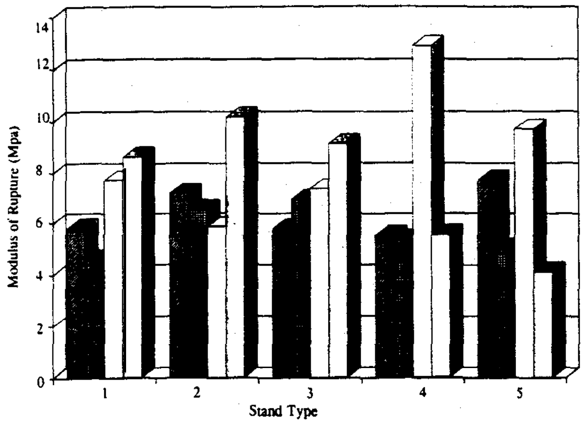

Fig. 1. A Stand comparison of modulus of rupture (MOR) of southern pine particleboard and fiberboard from five silviculturally different stands and two wood types. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish, FB-Outer denotes fiberboard manufactured from outerwood furnish, PB-Inner denotes particleboard manufactured from innerwood furnish, and PB-Outer denotes particleboard manufactured from outerwood furnish. ❑ : FB-Inner: ▩: FB-Outer; □: PB-Inner; ❑ : PB-Outer.

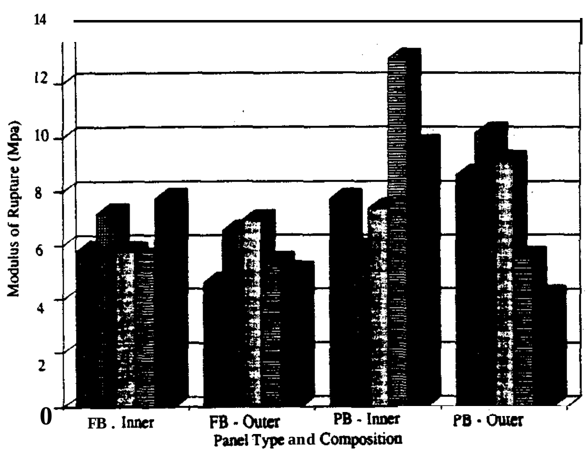

Fig. 2. A panel and wood type comparison of modulus of rupture (MOR) of southern pine particleboard and fiberboard from silviculturally different stands and two wood types. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish. FB-Outer denotes fiberboard manufactured from outerwood furnish, PB-inner denotes particleboard manufactured from innerwood furnish, and PB-Outher denotes particleboard manufactured from outerwood furnish. ❑ : Sudden Sawlog; ▩: Conventional; ▩: Natural Regen.; ▤: Single Tree Select; ■ : Crop Trees.

thus should not contribute to mechanical or physical property differences.

The compaction ratio was consistently greatly for innerwood than outerwood. This held true for both particleboard and fiberboard manufactured from all five stands (Table 2). It is generally recognized that a compaction ratio of 1.3 and greater is sufficient to promote proper bonding (Maloney 1977). All panels made from outerwood had a compaction ratio less than 1.3, and all but one of the innerwood panels showed a compaction ratio greater than 1.3. These results are in agreement with those of Pugel *et al.* (1989a) who found fast-grown wood to have a higher compaction ratio than mature wood for both particleboard and fiberboard. The innerwood used for this study likely displayed faster growth than wood obtained from the outerwood region.

Mechanical Properties

Modulus of rupture (MOR)

The mean MOR values are presented in Figures 1 and 2. The higher values for particleboard were expected due to the larger particle sizes and slightly higher panel densities than fiberboard. Statistically significant differences between the stands for a given wood type and product are given in Table 3. There were no significant differences between the means for particleboard from outerwood furnish. For particleboard innerwood, stand 4 (single tree selection) was significantly greater than the others. For fiberboard, the stands did not significantly differ for either outerwood or innerwood furnish.

It is interesting to note that stand 2 (conventional) gave the highest mean value for outerwood particleboard, stand 3 (natural regeneration) the highest mean value for fiberboard outerwood, stand 4 (single tree selection) the highest mean value for particleboard innerwood, and stand 5 (crop trees) yielded the highest mean value for fiberboard innerwood. It is therefore difficult to extend recommendations that endorse a particular silvicultural strategy for a particular panel product. Moreover, industry practice does 'not currently separate innerwood (juvenile) wood and out&wood (mature) furnishes. However, if a stand is harvested at such an age when the trees are still in the juvenile period of wood production, then inferences from the innerwood portion of this study would be valid. For a young stand, a silvicultural strategy similar to stand 5 (crop trees) could be beneficial for strong fiberboard panels and a scheme analogous to stand 3 (natural regeneration) should be beneficial for strong par-

Table 3. Comparison of loblolly pine particleboard and fiberboard mechanical properties by Tukey's test for significantly different means

Stand'-wood tvne	Particleboard			Fiberboard		
	MOR	MOE	IB	MOR	MOE	IB
1-Outerwood	A[2]	B	A	A	A	A
2-Outerwood	A	AB	A	A	A	A
3-Outerwood	A	A	A	A	A	A
4-Outerwood	A	AB	A	B	A B	A
5-Outerwood	A	B	A	B	A B	A
1-Innerwood	A	A	A	A	A	A
2-Innerwood	A	A	A	AB	B	A
3-Innerwood	A	A	A	B	A	A
4-Innerwood	A	A	A	B	A	A
5-Innerwood	A	A	A	B	A	A

[1] Stand 1 = Sudden sawlog. Stand 2 = Conventional. Stand 3 = Natural regeneration. Stand 4 = Single tree selection. Stand 5 = Crop trees. 'Within either wood type grouping, similar letters no significant difference exists between means for a particular property. Significant differences were declared at $a = 0.05$.

ticleboard. If a stand is old enough to be producing mature wood, then recommendations can not be directly drawn from this study because this study only produced panels from either innerwood or outerwood and did not use a mixed furnish. Moreover, most particleboard and fiberboard mills currently chip trees harvested from early thinning operations comprised almost entirely of juvenile wood or chips and planer shavings (juvenile and mature wood) from a nearby sawmill. Nevertheless, if a particular stand is old enough in which a vast majority of its wood is mature, then inferences can be drawn with the outerwood portion of this study. Consequently, stand 3 (natural regeneration) and stand 2 (conventional) would seem favorable for strong fiberboard and particleboard, respectively.

Mean MOE values are presented in Figures 3 and 4. The decreased particle size for fiberboard did not serve to greatly decrease the MOE of fiberboard for most of the stands at a given wood type.

Stand 3 (natural regeneration) yielded the highest mean values for both outerwood fiberboard and outerwood particleboard. This stand was significantly greater than stand 1 (sudden sawlog) and stand 5 (crop trees) for outerwood particleboard, but there were no significant differences for outerwood fiberboard. The stands varied slightly with regards to innerwood MOE. Particleboard manufactured from the innerwood furnishes did not significantly differ but all stands were significantly greater than stand 2 (conventional) for innerwood fiberboard. Pugel *et al.* (1989a) found particleboard and fiberboard mature wood panels to be slightly weaker than core wood panels.

Internal bond (IB)

The mean IB values are illustrated in Figures 5 and 6 and significant differences are shown in Table 3. The low IB values for fiberboard are indicative of unsatisfactory resin cure. Although the fiberboard IB values are unacceptable for most applications, they are still useful in determining differences between the stands and the wood types. The resin performed poorly but should have performed equally poor for all groups.

There were no significant differences detected for the particleboard or fiberboard IB mean values. Stand 2 gave

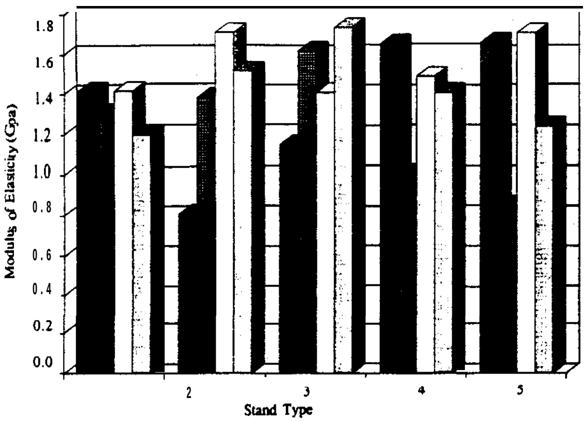

Fig. 3. A stand comparison of modulus of elasticity (MOE) of southern pine particleboard and fiberboard from five silviculturally different stands and two wood types. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish, FB-Outer denotes fiberboard manufactured from outerwood furnish, PB-Inner denotes particleboard manufactured from innerwood furnish, and PB-Outer denotes particleboard manufactured from outerwood furnish. ▨: FB-Inner; ❑ : FB-Outer; ☐: PB-Inner; ❑ l: PB-Outer.

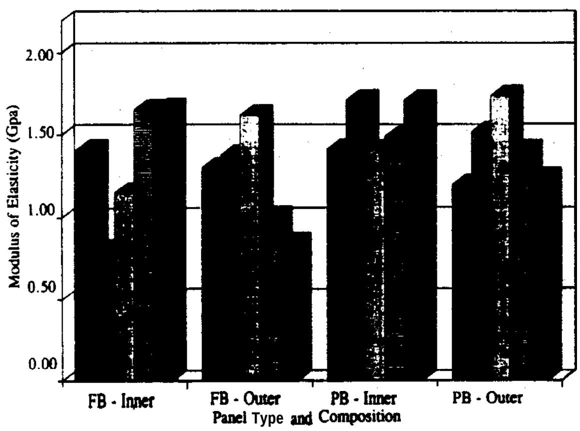

Fig. 4. A panel and wood type comparison of modulus of elasticity (MOE) of southern pine particleboard and fiberboard from five silviculturally different stands and two wood typles. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish, FB-Outer denotes fiberboard manufactured from outerwood furnish, PB-Inner denotes particleboard manufactured from innerwood furnish, and PB-Outer denotes particleboard manufactured from outerwood furnish. ■ : Sudden Sawlog; ▦: Conventional: ❑ : Natural Regen.; ⊟: Single Tree Select; ■ : Crop Trees.

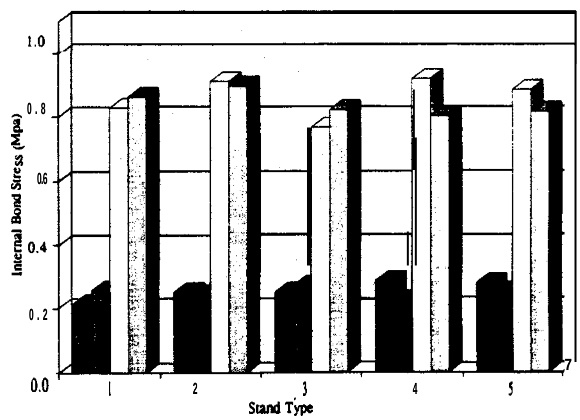

Fig. 5. A stands comparison of internal bond stress (IB) of southem pine particleboard and fiberboard from five silviculturally different stands and two wood types. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish, FB-Outher denotes fiberboard manufactured from outerwood furnish. PB-Inner denotes particleboard manufactured from innerwood furnish. and PB-Outer denotes particleboard manufactured from outerwood furnish. ▨: FB-Inner; ❑ : FB-Outer; ☐: PB-Inner: ▩: PB-Outer.

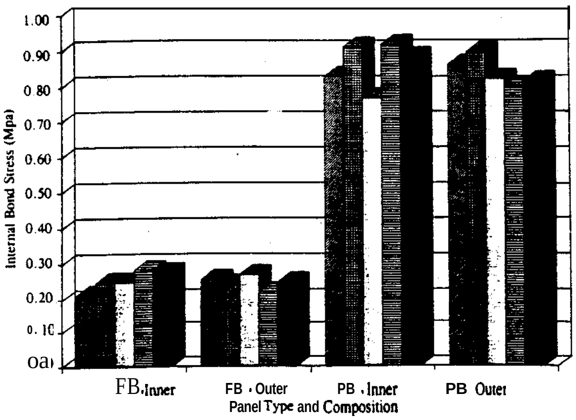

Fig. 6. A panel and wood type comparison of internal bond stress (IB) of southern pine particleboard and fiberboard from five silviculturally different stands and two wood types. Note: FB-Inner denotes fiberboard manufactured from innerwood furnish; FB-Outer denotes fiberboard manufactured from outerwood furnish, PB-Inner denotes particleboard manufactured from innerwood furnish, and PB-Outer denotes particleboard manufactured from outerwood furnish. ■: Sudden Sawlog; ▦: Conventional: ❑ : Natural Regen.; ▤: Single Tree Select; ■ : Crop Trees.

the highest mean for outerwood particleboard, stand 3 the highest for outerwood fiberboard, stand 4 the highest mean value for innerwood fiberboard and innerwood particleboard. Innerwood outperformed outerwood for three of the stands for both panel types. However, the difference between innerwood and outerwood were small for each stand.

Physical Properties

The mean values for 2 and 24h thickness swell are presented together with the mean values for 2 and 24 h water adsorption in Figure 7 and significant differences are shown in Table 4. Stand 4 (single tree. selection) was significantly the lowest for 2 h. thickness swell for fiberboard innerwood and also the lowest for particleboard outerwood, although it was not significantly different from stand 2 (conventional) or 3 (natural regeneration). Stand 2 (conventional) showed the lowest mean for fiberboard outerwood and stand 5 (crop trees) the lowest for particleboard innerwood. A somewhat similar pattern was exhibited for 24h thickness swell. However. stand 2 (conventional) was replaced by stand 1 (sudden sawlog) for the lowest thickness swell for fiberboard outerwood.

The favorable thickness swell performance of stand I (single tree selection) can largely be attributed to the comparatively lower panel densities for both panel types and wood types from this stand, particularly fiberboard innerwood and particleboard outerwood (Table 2). It has been previously shown that a strong relationship exists between panel density and thickness swell (Maloney 1977). Also, panels with high compaction ratios have been shown to produce durable juvenile wood composites but with the detrimental effect of higher thickness swell (Suchland and Xu 1989). Wasniewski (1989) showed that Douglas-fir flakeboard made from juvenile wood had low 24 h thickness swell due to the higher compaction ratio of this furnish. Kelly (1977) has shown that greater densification may restrict moisture from entering a panel and thus allow minimal swelling.

With regards to both 2 and 24h water adsorption, stand 3 (natural regeneration) gave the lowest mean values for fiberboard innerwood and particleboard outerwood, stand 2 (conventional) yielded the lowest mean for fiberboard outerwood, and stand 5 (crop trees) gave the lowest mean for particleboard innerwood. There were no significant differences detected for 2 or 24h water adsorption.

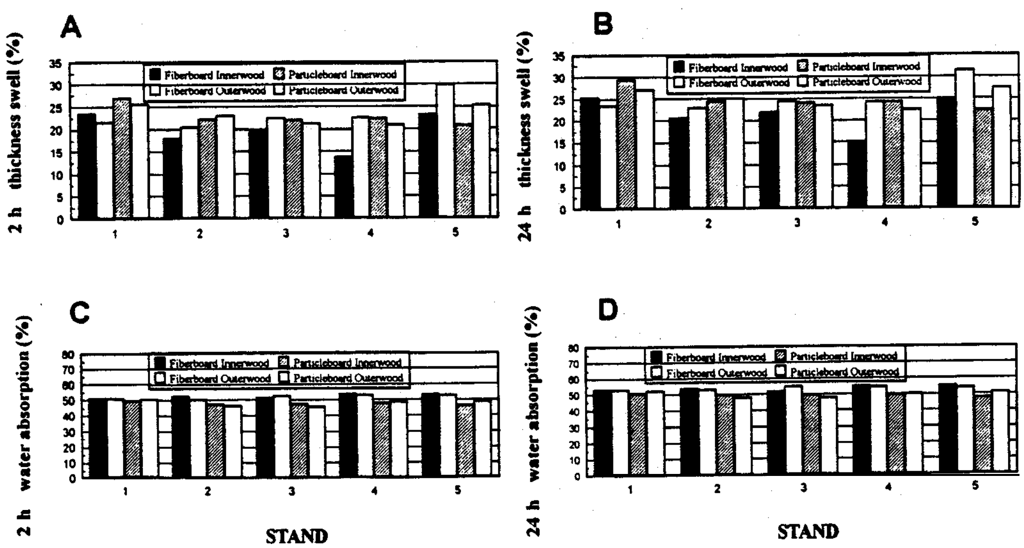

Fig. 7. (a) 2 h thickness swell, (b) 24h thickness swell. (c) 2 h water absorption, (d) 24 h water adsorption of loblolly pine particleboard and fiberboard from five silviculturally different stands and two wood types.

Table4. Comparison of loblolly pine particleboard and fiberboard physical properties by Tukey's test for significantly different means

Stand[1]-wood type	Particleboard				Fiberboard			
	2h TS[2]	24h TS	2h WA[2]	24h WA	2h TS	24h TS	2h WA	24h WA
1-Outerwood	A[3]	A	A	A	B	B	A	A
2-Outerwood	B	AB	A	A	B	B	A	A
3-Outerwood	B	B	A	A	B	B	A	A
4-Outerwood	B	B	A	A	B	B	A	A
5-Outerwood	A	A	A	A	A	A	A	A
1-Innerwood	A	A	A	A	A	A	A	A
2-Innerwood	B	AB	A	A	AB	AB	A	A
3-Innerwood	B	AB	A	A	AB	AB	A	A
4-Innerwood	B	AB	A	A	C	C	A	A
5-Innerwood	B	B	A	A	A	A	A	A

[1] Stand 1 = Sudden sawlog. Stand 2 = Conventional. Stand 3 = Natural regeneration. Stand 4 = Single tree selection. Stand 5 = Crop trees. [2] TS = thickness swell. WA = water adsorption. [3] Within either wood type grouping, similar letters indicate no significant difference exists between means for a particular property. Significant differences were declared at a = 0.05

Pugel et al. (1989 b) found that juvenile wood sources can produce composites that have adequate initial properties and durability, but inadequate dimensional stability when compared to mature wood composites. Our study found fiberboard outerwood to give higher 2 and 24h thickness swell mean values than fiberboard innerwood for four of the five stands. Particleboard outerwood gave higher 2 and 24h thickness swell mean values for 2 of the 5 stands. A reverse situation was observed for water adsorption. Fiberboard outerwood gave higher mean values for only 1 stand for both 2 and 24 h water adsorption. Particleboard outerwood was higher for 3 stands for both 2 and 24h water adsorption. It is emphasized that there were very small differences between the stands or wood types for water adsorption.

Conclusions

This research was initiated to determine the effect of silvicultural treatments and wood type on basic mechanical and physical properties of loblolly pine particleboard and fiberboard. Of the five stands investigated, stand 3 (natural regeneration) and stand 4 (single tree selection) usually yielded the highest mean values for most mechanical and physical properties. In all instances where stand 3 (natural regeneration) gave the most favorable mean values for a particular property, it was never significantly better than stand 4 (single tree selection).

This study has shown that innerwood composites do not have greater thickness swell or water adsorption than outetwood composites. Also, the MOR, MOE, and IB for innerwood and outerwood are very comparable for a particular stand and product. This study found innetwood composites to always have a higher compaction ratio than outerwood composites. However, the differences in panel densities were slight. Thus, differences in most mechanical and physical properties were minimal. We conclude that because the differences in most mechanical and physical properties were minimal, then both wood types from all stands can potentially be used to produce acceptable particleboard and fiberboard.

Acknowledgement

This paper (No. 96-22-0368) is published with the approval of the Director of the Louisiana Agricultural Experiment Station. The authors wish to gratefully acknowledge the assistance of Georgia-Pacific Co. at Crossett, AR for the veneer. and Hunt Plywood at Pollock. LA for peeling the veneer, and Borden Adhesive Co. at Alexandria, LA for the resin and technical assistance. The mention of company names or commercial products does not necessarily constitute endorsement, and the omission of company names or commercial products does not necessarily constitute lack of endorsement by Louisiana State University Agricultural Center or USDA Forest Service. This study was funded by the Louisiana Forest Products Laboratory and the Louisiana Agricultural Experiment Station.

References

American Society of Testing and Materials (ASTM). 1993a. Evaluating properties of wood-based fiber and particle panel materials. ASTM D 1037-93. Vol. 04.10. ASTM, Philadelphia. PA. pp. 167-196.

American Society of Testing and Materials (ASTM). 1993 b. Standard test methods for specific gravity of wood and wood-base materials. ASTM D 2395-83. Vol. 04.10. ASTM, Philadelphia, PA. pp. 379-386.

Baker, J.B. and L.M. Bishop. 1986. Crossett demonstration forest guide. General report R8-GR6. USDA For. Serv.. Southern Region. New Orleans, LA 55 pp.

Dix, B. and E. Roffael. 1995. Zum Verhalten des Splint- und Kemholzes der Lärche (*Larix decidua*) bei der Herstellung von feuchtebeständigen Spanplatten unter Einsatz verschiedener Bindemittel. Holz Roh-Werkstoff *53*, 357-367.

Dix, B. and E. Roffael. 1997a. Einfluß der Verkemung und des Baumalters auf die Eigenschaften von Spanplatten aus Kiefemholz (*Pinus sylvestris*). Teil 1: Kemholz und seine Eigenschaften. Holz Roh- Werkstoff 55, 25-33.

Dix, B. and E. Roffael. 1997b. Einfluß der Verkemung und des Baumalters auf die Eigenschaften von Spanplatten aus Kiefemholz (*Pinus sylvestris*). Teil 2: Physikalisch-technologische Eigenschaften und Fotmaldehydabgabe von Spanplatten aus Kern- und Splintholz der Kiefer. Holz Roh-Werkstoff *55*, 103-109.

Kelly, M.W. 1977. Critical literature review of relationships between processing parameters and physical properties of particleboard. Gen. Tech. Rept. FPL-IO. USDA For. Serv.. Forest Prod. Lab., Madison, WI.

Lelis. V.R. and E. Roffaei. 1995. Über einige verleimungsrelevante chemische Eigenschaften von Douglasiensplint und -kernholz. Holz-Zentralblatt. 121.66-68.

Lelis, V.R., E. Roffael, and G. Becker. 1994a. Zur Verleimbarkeit von Splint- und Kemholz der Douglasie (1) mit Phenolformaldehydharzen, Melamin-Harnsstoff-Phenol-Formaldehydharzen und Diiocyanat-Klebstoffen. Holz-Zentralblatt 120, 2144-2146.

Lelis, V.R., E. Roffael, and G. Becker. 1994b. Zur Verleimbarkeit von Splint- und Kemholz der Douglasie (2) mit Phenolformaldehydharzen, Melamin-Harnsstoff-Phenol-Formaldehydharzen und Diiocyanat-Klebstoffen. Holz-Zentralblatt *120*, 2181-2182.

Liang, B., S.M. Shaler, L. Mott and L. Groom. 1994. Recycled fiber quality from a laboratory-scale blade separator/blender. Forest Prod. J. 44 (7/8), 47–50.
Maloney, T.M. 1977. Modem particleboard and dry-process fiberboard manufacturing. Miller-Freeman, San Francisco. CA. p. 672.
Pugel. A.D.. E.W. Price, and C.Y. Hse. 1989a. Composites from southern pine juvenile wood. Part 1. Panel fabrication and initial properties. Forest Prod. J. 40 (I), 29-33.
Pugel. A.D.. E.W. Price. and C.Y. Hse. 1989b. Composites from southern pine juvenile wood. Part 2. Durability and dimensional stability. Forest Prod. J. JO (3), 57-61.
SAS Institute. Inc. 1989. SAS/STAT User's guide. Version 6, 4th ed.. Vol. 2. Cary, N.C. 846 pp.
Shupe, T.F., C.Y. Hse, E.T. Choong and L.H. Groom. 1997. Differences in some chemical properties of innerwood and outerwood from five silviculturally different loblolly pine stands. Wood Fiber Sci. 29 (1), 91-97.
Suchland. 0. and H. Xu. 1989. A simulation of the horizontal density distribution in a flakeboard. Forest Prod. J. 39 (5), 29-33.
Wasniewski, J.L. 1989. Evaluation of juvenile wood and its effects on Douglas-fir structural composite panels. Ed. T.M. Maloney. Proc. 23rd Wash. State Univ. Inter. Particleboard/Composite Materials Symp. Pullman. WA. pp. 159–173.

Received December 15th 1997

Todd F. Shupe[1]
Forest Products Specialist
Louisiana Cooperative Extension Service
Louisiana State University Agricultural Center
P.O. Box 25100
Baton Rouge, LA 70803
U.S. A.

Chung Y. Hse[2]
Principal Wood Scientist
USDA Forest Service
Southern Research Station
2500 Shreveport Highway
Pineville. LA 71360
U.S. A.

Elvin T. Choong[2]
Professor
School of Forestry. Wildlife. and Fisheries
Louisiana State University Agricultural Center
Baton Rouge. LA 70803
U.S. A.

and

Leslie H. Groom[2]
Research Technologist
USDA Forest Service
Southern Research Station
2500 Shreveport Highway
Pineville, LA 71360
U.S. A.

[1] Author to whom correspondence should be directed.
[2] Addresses where the work was performed.