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# Composites from southern pine juvenile wood. Part 1. Panel fabrication and initial properties

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**Abstract**

Flakeboard, particleboard, and fiberboard panels were manufactured from four different sources of southern pine (*Pinus taeda* L.) juvenile wood. The sources were: 1) fast-grown trees; 2) the inner core of older trees; 3) branches; and 4) tops. The juvenile wood particle sizes and panel densities were similar to those used for control panels made from mature southern pine wood. Overall, the initial (72°F, 66% relative humidity conditions) modulus of elasticity, modulus of rupture, and internal bond of the juvenile wood composites were comparable to the mature wood composite values. However, the higher compaction ratios needed for the juvenile wood panels have implications and possibilities that may affect the commercial use of this furnish. In future publications, the durability and dimensional stability of juvenile wood composites (Part 2) and the properties of panels made from mixtures of juvenile and mature wood particles (Part 3) will be reported.

Juvenile wood can significantly degrade the performance of lumber (12), plywood (5), and paper (3). However, according to Maloney (6), "The extent of the deleterious effects on the properties of composition boards made from juvenile wood is unknown." Specifically, very little is known about the effect of juvenile wood on particle-based composites such as flakeboard, particleboard, and fiberboard.

This study examined the impact of southern pine juvenile wood on the performance of wood composites. Panels were made from mature wood and four sources of juvenile wood. Three different sizes of particles were pressed at two panel densities for each wood type. The procedure used for making these panels and the initial (72°F, 66% relative humidity (RH) exposure) mechanical properties are presented in this paper. Other papers will report on the durability and dimensional stability of the juvenile wood composites (10) and the properties of panels made from mixtures of juvenile and mature wood particles (11).

## Procedure

All the juvenile and mature wood collected was loblolly pine (*Pinus taeda* L.) from sites in central Louisiana. The term juvenile wood is used herein to describe the four different types of nonmature wood furnish: fast-grown, core, branches, and tops. The wood from 8-year-old, plantation-grown trees was sampled to represent fast-grown material. Weed control, fertilization, and mowing treatments produced trees that averaged 7 inches in diameter at breast height (DBH). Material from 8-foot-long butt and second logs was obtained from 32 trees. An inner core (wood formed within the first 10 yr.) of juvenile wood was obtained as green lumber from 40- to 50-year old trees. The lumber (nominal 2 by 6 in.) chosen contained the pith and presented less than 10 growth increments on each end. Branches and tops were collected from an ongoing harvesting operation of a naturally grown 50-year-old stand. The material was 4 to 6 inches at the large end. A mature wood sample was collected from the same source as the core. Lumber (nominal 2 by 6 in.) from the outside part of the log was

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TABLE 1. — *Particle size analysis of southern pine juvenile wood composite furnishes.*

| Particle type | Wood type: Mature | Fast-grown | Core | Branches | Tops |
|---|---|---|---|---|---|
| | 2.998 | 3.002 | 3.002 | 2.986 | 3.015 |
| | 0.698 | 0.720 | 0.750 | 0.740 | 0.765 |
| | 0.019 | 0.021 | 0.023 | 0.020 | 0.021 |
| | | | | | |
| | 15 | 31 | 25 | 18 | 25 |
| | 42 | 32 | 42 | 35 | 32 |
| | 23 | 21 | 18 | 27 | 26 |
| | 11 | 8 | 8 | 12 | 10 |
| | 9 | 8 | 7 | 8 | 7 |
| | | | | | |
| | 2 | 4 | 4 | 1 | 2 |
| | 17 | 17 | 27 | 11 | 20 |
| | 31 | 31 | 28 | 30 | 29 |
| | 18 | 19 | 15 | 20 | 19 |
| | 32 | 29 | 26 | 38 | 30 |

[a] Dimensions for each wood type were determined from 25 randomly selected whole flakes, measured at 72°F, 66 percent relative humidity conditions.
[b] Percentage of material retained on Bauer-McNett screen sizes. P-20 indicates material passing through the No. 20 size screen.

TABLE 2. — *Southern pine juvenile wood specific gravities, panel densities, and compaction ratios.*

| Source | Wood type: Mature | Fast-grown | Core | Branches | Tops |
|---|---|---|---|---|---|
| Flakes | | | | | |
| Specific gravity[a] | 0.46 | 0.38 | 0.42 | 0.44 | 0.42 |
| Density[b] | 28.7 | 23.7 | 26.2 | 27.5 | 26.2 |
| Flakeboard | | | | | |
| 40 pcf | | | | | |
| Panel density | 39.9 | 41.0 | 40.7 | 40.4 | 40.8 |
| Compaction ratio[c] | 1.39 | 1.73 | 1.55 | 1.47 | 1.56 |
| 44 pcf | | | | | |
| Panel density | 44.3 | 45.4 | 44.9 | 44.2 | 44.3 |
| Compaction ratio | 1.54 | 1.92 | 1.71 | 1.61 | 1.69 |
| Particleboard | | | | | |
| 40 pcf | | | | | |
| Panel density | 37.8 | 37.4 | 38.8 | 38.8 | 38.5 |
| Compaction ratio | 1.32 | 1.58 | 1.48 | 1.41 | 1.47 |
| 44 pcf | | | | | |
| Panel density | 41.4 | 41.5 | 42.3 | 41.8 | 41.9 |
| Compaction ratio | 1.44 | 1.75 | 1.61 | 1.52 | 1.60 |
| Fiberboard | | | | | |
| 40 pcf | | | | | |
| Panel density | 37.1 | 37.4 | 36.7 | 36.9 | 37.0 |
| Compaction ratio | 1.29 | 1.58 | 1.40 | 1.34 | 1.41 |
| 44 pcf | | | | | |
| Panel density | 41.0 | 40.9 | 40.7 | 40.6 | 40.9 |
| Compaction ratio | 1.43 | 1.73 | 1.55 | 1.48 | 1.56 |

[a] Based on ovendry weight and volume at 72°F, 66 percent relative humidity conditions of 25 randomly selected flakes of each wood type.
[b] Density based on ovendry weight and volume at 72°F, 66 percent relative humidity, units are in pcf.
[c] Compaction ratio calculated by dividing panel density by flake density.

selected. The bark was removed from all the wood types and all the material was kept in the green condition prior to comminution.

The material was processed into three types of particles: flakes, particles, and fibers. The material for flakes, from all sources, was sawn into 0.75- by 3- by 3-inch blocks. Flakes were generated on a laboratory disk flaker set at a thickness of 0.020 inch. Particles were generated by chipping and then ring-flaking at a thickness of 0.025 inch. Fibers were manufactured by chipping and processing through a single disk atmospheric refiner with plate clearance set at 0.020 inch.

A sample of whole flakes was measured to determine the dimensions and density for each wood type. Particle and fiber size distributions were determined on a Bauer-McNett screen system. Samples of each material, weighing 100 g each, were processed five times and the results were averaged. All the size classifications were conducted on material conditioned to 72°F, 66 percent RH. Prior to blending, all furnishes were dried to less than 3 percent moisture content (MC). All particles were sprayed with a liquid phenolic resin (55% solid content) formulated for flakeboards. Resin was applied at the rate of 5 percent resin solids based on the ovendry weight of the wood particles. No wax was applied. The same drum blender, sprayer, and blending time were used for each material and furnish type. Panels were made at two densities, 40 and 44 pcf for each wood type and particle combination. Mats were hand-felted and randomly oriented. 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 6-minute press cycle. The platen temperature was 375°F. The resulting panels were 7/16 by 22 by 32 inches. Panels were stacked on edge for 24 hours prior to cutting individual specimens.

Three bending samples (3 by 17 in.) were randomly selected from each of the three panel replications (nine bending specimens for each combination of wood type, particle type, and density level). These specimens were stored on stickers for 4 weeks at 72°F and 66 percent RH.

The procedures for the determination of modulus of elasticity (MOE), modulus of rupture (MOR), and internal bond (IB) as prescribed by ASTM D 1037-87 (1) were followed. Two IB specimens and an MC-density specimen were cut from undamaged portions of the failed bending specimens.

## Results

### Particle size analysis

The analysis of particle sizes is presented in Table 1. The comminution processes produced similar size distributions for all wood types. Because the size differences within a particle type were small, it was assumed that this factor did not influence the panel properties of one wood type any more than another.

While only whole flakes were measured, the flaking method and the gentleness of the laboratory blending and forming processes ensured a high proportion of whole flakes in the finished panel. The particle and fiber sizes were analyzed on the same set of screens to emphasize the differences between these two particle types. Consequently, the fibers had very little retention on the No. 5 screen and a high proportion passing the No. 20 screen. It should also be emphasized that the particleboard and fiberboard manufactured in this study are intended mainly to compare particle size effects and are not necessarily representative of commercial furnishes.

### Panel densities and compaction ratio

The specific gravities (SG), panel densities, and compaction ratios for all wood types are presented in Table 2.

The panel densities within each density level were not significantly different for any of the wood types. It was assumed that panel density was not a factor in the mechanical properties of the panels of the same particle type and density level.

The target panel densities of 40 and 44 pcf were met only for the flakeboards. Particleboard and fiberboard densities were lower than targeted by 2 to 3 pcf. The lower densities were due to the mats spreading out during press closure. Although the target densities were not achieved, there was still good separation between the low and high density levels (about 4 pcf), and they will be referred to at the target levels in the text.

The compaction ratios for the panels made from fast-grown wood were highest for all of the panel types. The fast-grown 44-pcf flakeboard panel had a compaction ratio that nearly doubled the density of the wood furnish. The compaction ratios for the particleboard and fiberboard, even at the lower actual density levels, remained high enough (1.3 and above) to promote good bonding (7).

## Mechanical properties

The average MOE values are presented in Figure 1. Average MOE ranged from 500,000 to 800,000 psi for flakeboard, 400,000 to 500,000 psi for particleboard, and 250,000 to 350,000 psi for fiberboard. The higher density (44 pcf) level increased MOE by about 100,000 psi for all combinations. As expected, MOE decreased with decreasing particle size. The differences in MOE between wood types also decreased with smaller particle size. Statistically significant differences between the means within each density level are given in Table 3. The flakeboard from fast-grown and branch wood was significantly less stiff at both density levels. Some factors that may account for low panel MOE are the panel density profile, low longitudinal MOE of the furnish (600,000 psi has been estimated for fast-grown loblolly pine with 0.38 SG (9)), and through-the-flake grain angle (2). For fiberboard, all wood types produced equivalent panel MOEs.

The average MOR values are presented in Figure 2. The average MOR for flakeboard was from 4,500 to 5,500 psi, 2,500 to 3,000 psi for particleboard, and 2,000 to 2,500

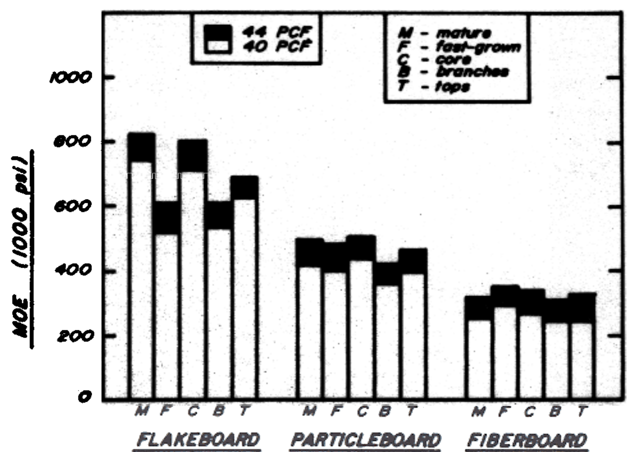


Figure 1. — Modulus of elasticity (MOE) of composites made from southern pine juvenile wood.

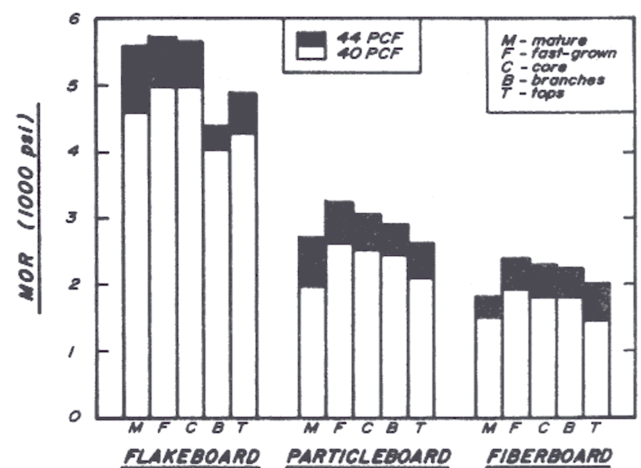


Figure 2. — Modulus of rupture (MOR) of composites made from southern pine juvenile wood.

TABLE 3. — *Comparison of southern pine juvenile wood composite initial mechanical properties by Scheffe's test for significantly different means.*[a]

| Panel density/ wood type | Panel type/property | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flakeboard | | | Particleboard | | | Fiberboard | | |
| | MOE | MOR | IB | MOE | MOR | IB | MOE | MOR | IB |
| 40 pcf | | | | | | | | | |
| Mature | A | AB | A | AB | C | B | A | B | B |
| Fast-grown | C | A | A | B | A | B | A | A | A |
| Core | AB | AB | A | A | A | A | A | AB | B |
| Branches | C | B | A | B | AB | B | A | AB | B |
| Tops | B | AB | A | B | BC | B | A | B | A |
| 44 pcf | | | | | | | | | |
| Mature | A | A | B | A | B | B | A | B | D |
| Fast-grown | B | A | B | AB | A | BC | A | A | A |
| Core | A | A | B | A | AB | A | A | A | C |
| Branches | B | B | A | B | AB | BC | A | A | B |
| Tops | B | AB | B | AB | B | C | A | B | B |

[a] Within each density level, like letters indicate no significant difference between means for that property. Significant differences were determined at the 5 percent level. A pertains to the group of means with the highest average value, B to the group with the second highest average values, C to the third highest average values, and D to the fourth highest average values.

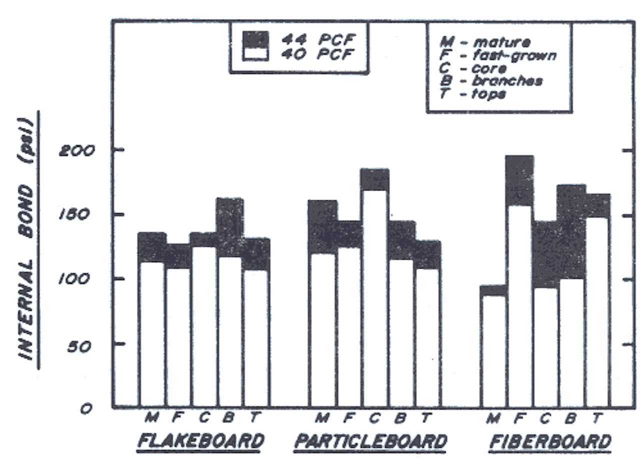


Figure 3. — Internal bond (IB) of composites made from southern pine juvenile wood.

psi for fiberboard. The higher density level increased the strength by 500 to 1,000 psi for all panel types. Significant differences between wood types are presented in Table 3. As opposed to the MOE results, the fast-grown material produced the highest MOR values for each of the particle types. Mature wood panels were weaker; more so for particleboard and fiberboard. Decreased particle size did not reduce differences in MOR between wood types, as was the case for MOE.

The IB results are presented in Figure 3 and the significant differences are presented in Table 3. IB values for all combinations ranged from 100 to 200 psi. Higher density panels always produced higher IB values, but the effect ranged from increases of 10 psi to nearly 50 psi. There was very little response of the mature wood fiberboard panel to increased panel density, especially when compared to the large gains made by the fast-grown, core, and branch wood panels. There was almost no difference between the IB of the wood types for flakeboard. Branch wood produced an exceptionally high 44 pcf IB value, almost 200 psi. Core wood and fast-grown wood produced exceptionally high values for particleboard and fiberboard, respectively.

## Discussion

For most of the particle size and density combinations, the juvenile wood composites performed as well as, if not better than, the mature wood composite. Assuming that juvenile wood mechanical properties (longitudinal MOE and MOR) are lower to begin with, the higher compaction ratios contribute a large part of the improved performance of the juvenile wood composites (4). In addition to increasing panel mechanical properties, higher compaction ratios also affect important aspects of processing and bonding.

Assuming that a given panel density is desired, compared to mature wood, a larger volume of juvenile wood will have to be harvested, debarked, sized, dried, blended, formed, and pressed. Among other considerations, larger capacity conveyors, blenders, and presses will be required. To maintain the same output, more input is required. This additional volume of input is directly proportional to the density of the wood. In this study, about 20 percent more fast-grown wood than mature wood was required to make panels with the same density.

An alternative to making the same density panel is to make the same compaction ratio panel. From Table 1, this would be roughly equivalent to comparing the 44 pcf mature wood values to the 40 pcf values for the juvenile wood types. Figures 1, 2, and 3 show that mature wood is superior (except for fiberboard IB) to juvenile wood at roughly equivalent compaction ratios. But this does not mean that panels made from juvenile wood could not pass commercial standards.

A third alternative to making panels that are either the same density or the same compaction ratio is to produce a low density panel using juvenile wood furnish. Using the fast-grown material of this study, a 31 pcf panel could be produced at a compaction ratio of 1.3:1. Of course, the properties of such a panel need to be determined, as well as the market for such a product.

A different aspect of the compaction ratio effect is bonding efficiency. Higher compaction ratios bring more particles into contact with each other and presumably more bonds will be formed. This is not only a physical fact but is truly critical for the successful bonding of low density material. At the same panel density, a larger volume of juvenile wood particles is required. However, the resin content of the panel is based on the weight of the wood particles. Thus, the same amount of resin is spread on a greater number of juvenile wood particles. For particles of known geometry, the resin coverage can be calculated (8). Given the flake dimensions of Table 1, the fast-grown material had 10 percent less resin by weight per flake than a mature wood flake. If the flake dimensions were equal, each fast-grown flake would have received about 20 percent less resin.

A final aspect of compaction ratio is the physical component. At a compaction ratio of 2, on the average, the particles are compressed into half their original volume. Even at lower average compaction ratios, local variations can lower panel properties due to particle damage (13). This damage may be mitigated by factors such as a lower longitudinal MOE (in the case of juvenile wood), which allows particles to be bent rather than broken.

Certainly, the higher compaction ratios at the given panel density improve the properties of composites from juvenile wood sources. Just as certain are the many consequences of using high compaction ratios, as discussed above, and for durability and dimensional stability, as will be reported in Part 2 (10).

## Conclusions

In general, the MOE, MOR, and IB of composites made from southern pine juvenile wood were comparable to those properties of mature wood composites. Particle sizes and panel densities were equivalent for all wood types. Because the juvenile wood types were lower density than the mature wood, the compaction ratios were higher. While the higher compaction ratio developed equivalent properties, it has a number of implications and possibilities that affect the commercial use of juvenile wood furnish.

The results of this study are encouraging for the utilization of juvenile wood in composites such as flakeboard, particleboard, and fiberboard. Other parts of this research will report on the durability and dimensional stability of juvenile wood composites and the effect of juvenile/mature wood furnish mixtures on panel properties.

This initial investigation has suggested other areas of research on juvenile wood composites. The properties of low density panels from low density juvenile wood furnish (fast-grown trees) should be studied because they might provide a new market for this material. An assessment of the commercial processing of juvenile wood might include bark removal, optimal particle sizes, and production problems due to the increased volume of furnish. Also, the density profile of juvenile wood composites should be measured and optimized. Finally, a more indepth study might include characterizing the physical, anatomical, and mechanical properties of the juvenile wood source so the characteristics of the panels could be related back to the characteristics of the furnish.

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