Slash Pine Rootwood in Flakeboard

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Abstract

Flakes 3 inches along the grain, 3/8-inch wide, and 0.02 inch thick were machined from the taproots (with 6-inch-high stump) and second logs of eight 31-year-old slash pines. Specific gravity (O.D. weight, green volume) of stems averaged 0.52; rootwood averaged 0.43 and decreased sharply with depth below ground. Forty-four-lb./cu. ft. structural-type particleboards were prepared with random orientation of flakes and 5 percent phenol-formaldehyde solids. Stemwood boards were stiffer (737,000 psi MOE) than rootwood boards (643,000 psi MOE), but bending strength was lower (4,800 psi MOR) for stemboards than for rootboards (5,500 psi MOR). MOE/MOR ratio was 155 for stemboards and 118 for rootboards. The two types of boards did not differ in nail-withdrawal resistance (96 and 97 lb.). Internal bond of rootboards (114 psi) was almost double that of stemboards (60 psi); the difference was associated in part with the greater densification of rootwood (x 1.66) as compared with stemwood (x 1.36). Root flakes were more conformable but had higher proportions of grain deviation and damaged surfaces. Rootboards had greater dimensional movement in both planes, greater soaked moisture content, greater thickness springback, and greater recovery from linear swell. Interrelations of board properties differed for the two materials. Differences appeared to be primarily due to anatomical characteristics, lower inherent strength of rootwood, degree of densification, and machinability.

The stump and taproot of pulpwood-size pines contain substantial quantities of fiber that are not recovered in present harvesting practice. Previous work (Howard 1973) has shown the amount of fiber in these portions to be 25 to 30 percent of merchantable stem dry weight in 22-year-old slash pines. Specific gravity is lower in rootwood than in stemwood, but the chemical

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composition of the two wood types does not differ greatly in young trees.

Except for trees grown on boggy soil or impervious clay, the bulk of the root system is comprised of a large carrot-shaped taproot that can be removed from the ground without excessive soil disturbance.

Information on below-ground wood is meager. Aside from pulping and naval stores studies, no attempts to utilize stumps and roots have been reported. Fegel (1941) stated that, in conifers, strength properties of rootwood are inferior to those of stemwood. Howard (in Koch 1972, pp. 563-569) described anatomy of southern pine roots as highly variable and often showing characteristics of juvenile wood. Other investigators (Gerry 1915; Sproull et al. 1957; Manwiller 1972) found that root fibers of southern pines are longer and have larger diameters and thinner walls than fibers of the trunk.

To explore the possibility of using rootwood as a raw material for particleboard, structural-type boards composed of random-oriented flakes were prepared from stems and from the taproots (including stumps) of the same trees. Flakes were 3/8-inch wide, 0.02 inch thick, and 3 inches along the grain. It was felt that boards made from flakes of these dimensions should clearly reveal the differences in performance of the two wood types, since flakes with a large length/thickness ratio tend to maximize board strength properties.

In this paper, the term *rootwood* will refer to the taproot plus a stump 6 inches high. *Stemwood* will refer to the second 8-foot log above stump level.

Sixteen slash pines (DBH 9 to 11 inches, OB) were selected from a 31-year-old stand on sandy loam soil in central Louisiana. Trees were easily uprooted with a backhoe. Several shallow scrapes were first made around the base to sever a portion of the lateral roots, and then trees were uprooted by pushing. The taproot system was cut off 6 inches above ground. The relatively small holes were quickly filled by the backhoe. Remaining lateral roots were hand-trimmed. High-pressure hoses were used to clean the roots before they were photographed (Fig. 1). All material was stored under water spray until converted into flakes.

To insure adequate material from each tree, the eight trees with the largest and most uniform taproots were chosen for flaking. Stem and rootwood were cut into bolts 2 feet long. Specific gravity (ovendry weight, green volume) was determined from 1-inch-thick disks taken from the ends of each bolt; the centers of the disks were excluded, as the lathe on which flakes were cut left a 2-inch core unutilized. The dry weight of flakes from each bolt was used to calculate the weighted flake specific gravity of each 8-foot stem and each root.

Veneer ribbons 3 inches wide and 0.02 inch thick were peeled on a metal-cutting lathe. A thickness of 0.015 inch had been planned, but 0.02 inch was found necessary to obtain intact ribbons from portions of some roots. Ribbons were then fed into a clipper to produce flakes 3/8-inch wide. Flakes were ovendried at 215°F, weighed, and sealed in plastic bags.

Just prior to board formation, flakes from each tree and each wood type were combined, and the moisture

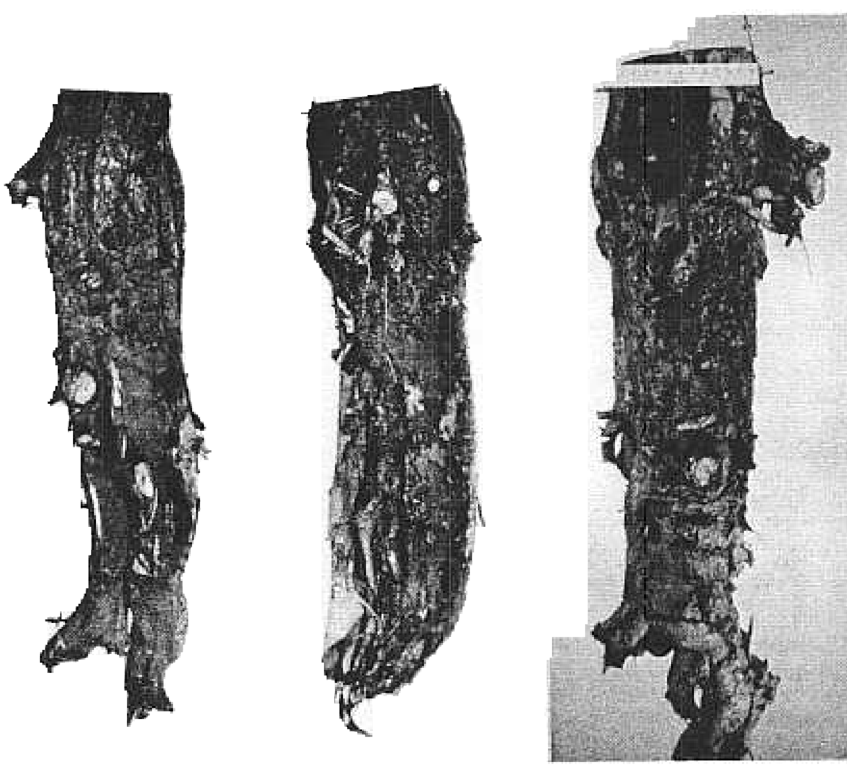

Figure 1. — Trimmed taproots with 6-inch stump attached. Trees were 9 to 11 inches in DBH.

content was checked. Sixty-four boards (8 trees × 2 wood types × 4 replications) were prepared to the following specifications:

- Density—44 lb./cu. ft.
- Resin—laboratory-prepared phenol-formaldehyde; 5 percent solids based on dry weight of flakes
- Moisture content of mat—10 percent
- Board size—14 by 14 by 1/2 inches
- Press closing time—45 sec.
- Pressing—7 min. at 325°F
- Pressure—935 psi on closing, gradual decompression to 30 psi 1 minute before opening.

Resin was applied by spraying in a tumbler blender.

Boards were conditioned at 72°F and 50 percent relative humidity prior to cutting. Five tests were made on each board. The cutting plan for specimens is shown in Figure 2:

- Static bending—3 samples
- Internal bond—5 samples
- 6d nail-withdrawal resistance—3 samples, 3 measurements on each
- Dimensional change, VPS (vacuum-pressure-soak method, Heebink 1967)—two soak strips, one drying strip
- Density (ovendry wt./green vol.)—VPS (each of three strips) bending (area of failure, 3 strips) nail-withdrawal (entire specimen, 3 samples)

Tests were conducted according to ASTM Standard D 1037-64 for all properties except dimensional stability, for which the 22-hour VPS method was used. Additional measurements were added to the original VPS procedure to obtain information on density and springback of soak strips after redrying. Two soak strips were used to insure reliability of values, and mathematical expressions were modified to segregate drying and swelling influences. Results were compared by analysis of variance, and relationships of the various properties were examined by simple regression.

Results

Stemwood was denser than corresponding rootwood in all trees:

Specific gravity			
Stemwood	Rootwood	Stemwood	Rootwood
0.48	0.39	0.53	0.46
.49	.42	.54	.46
.50	.42	.55	.41
.51	.42	.57	.49

Rootwood specific gravity was highest in the stump and decreased rapidly down the taproot, as illustrated in Figure 3. Specific gravity of rootwood is low because true latewood bands are infrequent and usually narrow, and most cells have thin walls with large lumens. Such cells are easily deformed by mechanical forces. Pitting in rootwood is sometimes suggestive of high fibril angle, which would reduce dimensional stability of the wood.

Roots also appeared less machinable than stemwood. They yielded a high proportion of flakes with distorted grain and rough surfaces. Sloping grain weakens the flake by allowing diagonal shear failure under tensile stress. In addition, fiber tear-out was frequent in the lower portions of taproots. All these defects expose severed fiber ends, resulting in high surface porosity.

Uniform random distribution was somewhat difficult to achieve with 3-inch-long flakes; they tended to bridge across, rather than fit into voids. Stemboards contained fewer flakes, and stem flakes were less conformable than root flakes during pressing (Fig. 4). Thus, stemboards were more prone to have gaps between ends of flakes. Such discontinuities cause localized variation in strength properties, particularly internal bond and modulus of rupture.

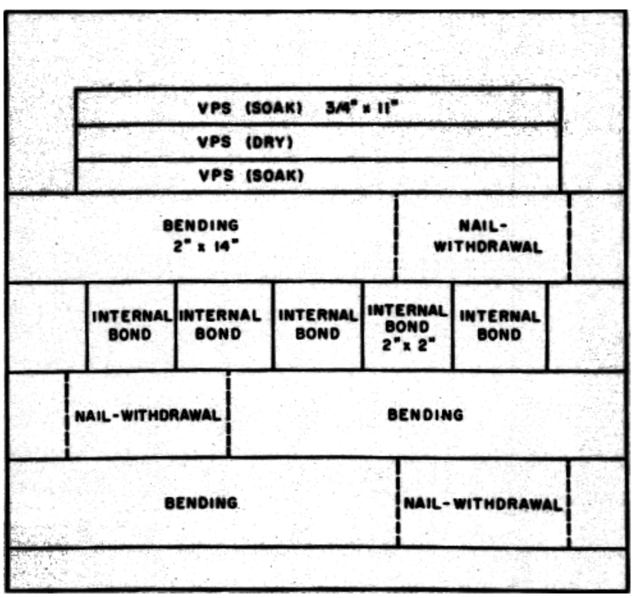

Figure 2. — Cutting scheme for testing. Nail-withdrawal specimens were cut from unfractured ends of bending strips.

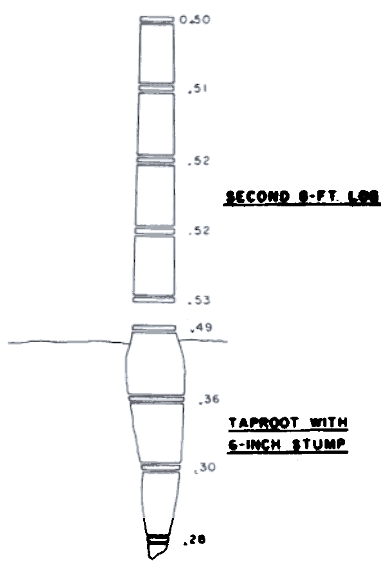

Figure 3. — Typical specific gravity variation found along the length of stump-taproots and stem samples. A marked decrease occurred below ground level.

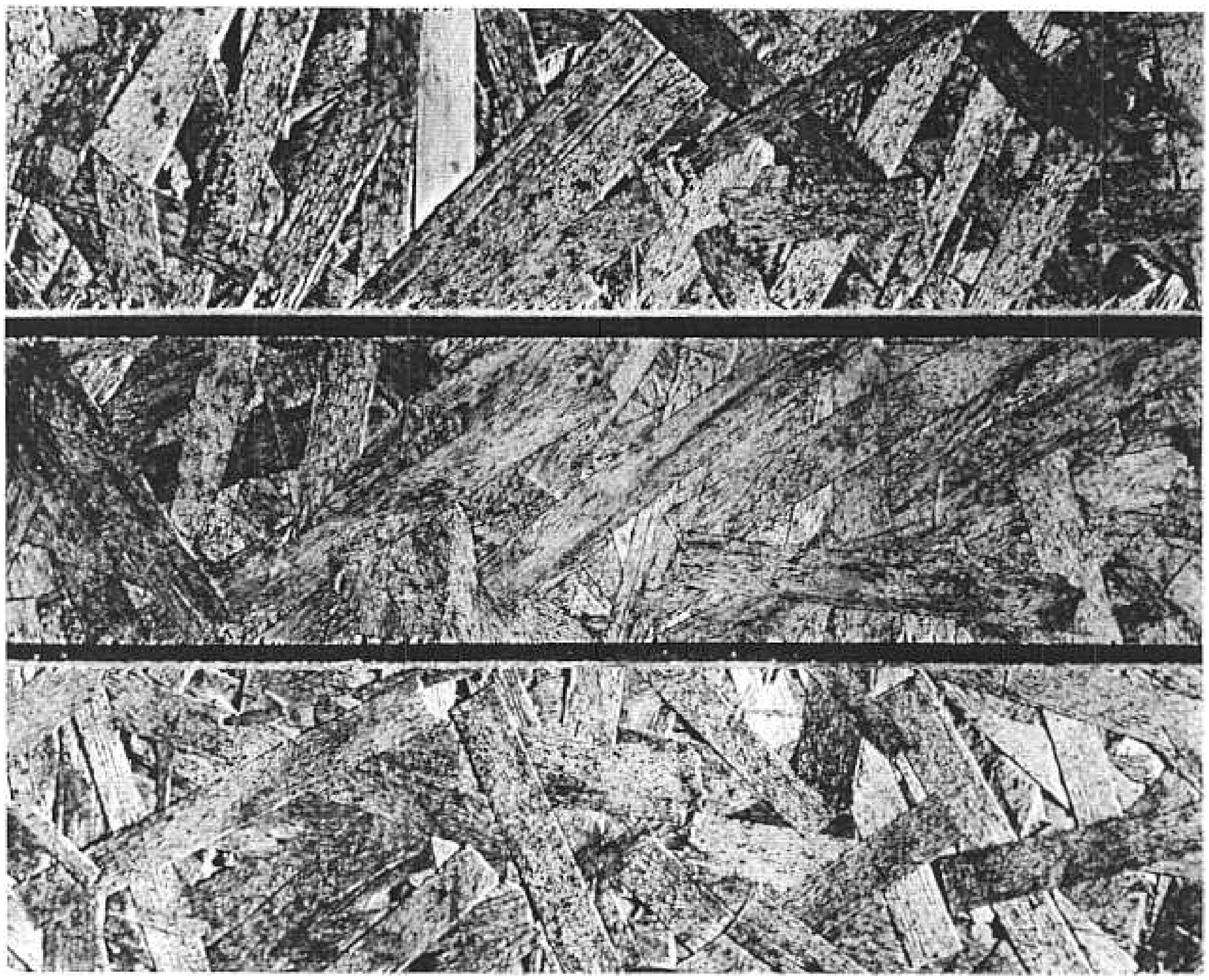

Figure 4. — Flakeboard surfaces demonstrate the greater conformability of rootwood. Top: Stemwood of tree 2 (sp.gr. = 0.57). Center: Rootwood of tree 2 (sp.gr. = 0.49). Bottom: Stemwood of tree 8 (sp.gr. = 0.49) has been densified to the same degree as rootwood in center.

Properties of the boards are given in Tables 1 and 2. Nail-withdrawal resistance was the only property that did not differ significantly (0.05 level) between the two wood types. Stemboards were stiffer, but had lower bending strength, than rootboards. MOE/MOR ratios thus differed greatly.

Internal bond for rootboards was almost twice that for stemboards. The less dense material yields a bulky mat that is compacted considerably during pressing; the flakes are also readily conformable. The consequent improved flake contact increases bond strength and modulus of rupture, despite the lower resin spread per unit of surface.

Rootboards had greater dimensional movement in both planes (Figs. 5 and 6), greater soaked moisture content, and greater thickness springback.[1] Differences in dimensional stability of boards from the two wood types appear to be due primarily to characteristics of the

[1]Springback is the irreversible thickness change remaining after the soaked specimen is redried, and is expressed as a percentage of original board thickness.

Table 1. — SPECIFIC GRAVITY AND DENSIFICATION RATIO OF FLAKEBOARDS MADE FROM SLASH PINE STEMS AND STUMP-TAPROOT SYSTEMS.

	Mean	Std. dev.	Range
Board density			
Stem	44.0	±1.6	
Root	44.0	1.4	
Wood specific gravity			
Stem	0.52	.03	
Root	.43	.03	
Densification ratio (board density/wood density)			
Stem	1.36	.08	1.23 to 1.46
Root	1.66	.12	1.44 to 1.84

Table 2. — PROPERTIES OF 44-LB./CU. FT. FLAKEBOARDS MADE FROM SLASH PINE STEMWOOD AND ROOTWOOD FROM THE SAME TREES.

	Stem		Root	
Property	Mean	Std. dev.	Mean	Std. dev.
MOR (psi)	4,800	±580	5,500	±670
MOE (thousand psi)	737	53	643	47
Nail withdrawal (lb.[1])	96	19	97	13
Internal bond (psi)	60	19	114	21
MOE/MOR	155	.17	118	.08
VPS:				
Soaked MC (percent)	108	6	114	8
Thickness swell (percent[2])	26.8	3.0	30.2	5.0
Thickness total change (percent[3])	29.5	3.1	32.7	5.0
Thickness springback (percent[4])	15.2	2.8	21.7	4.7
Linear swell (percent[2])	.40	.07	.52	.07
Linear drying change (percent[5])	—.18	.03	—.26	.03
Linear total change (percent[3])	.58	.08	.79	.09
Redried length (percent less than original[4])	—.10	.05	—.38	.05

[1]Nonsignificant difference at 0.05 level.

[2]Original (5 percent MC) to saturated.

[3]O.D. to saturated, i.e., drying shrinkage plus swell during soaking.

[4]Original to saturated to redried; compared to original.

[5]Original to O.D.

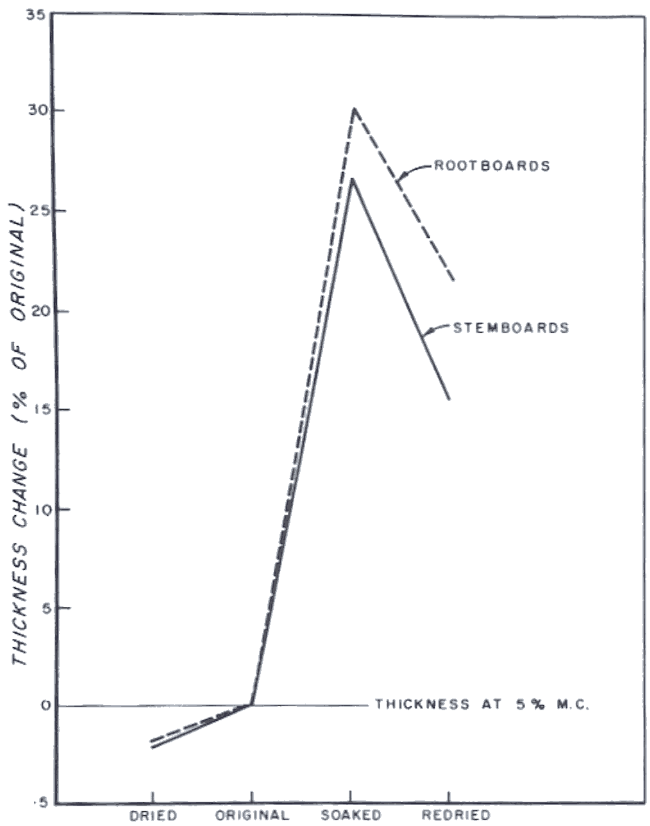

Figure 5. — Thickness changes in flakeboards tested by VPS method. Drying change comprised only a small portion of total thickness change. Both swell and final thickness were greater in rootboards than in stemboards.

original wood, and to the quality of flakes produced from each. Influences within the board are difficult to isolate. Numerous factors are involved, and effects of some are contradictory to varying degrees. Higher densification of root flakes should increase the potential for springback, but the resulting improved bonding has an opposing effect. Both factors should tend to inhibit the rate of water absorption. Grain deviation and damaged surfaces in root flakes would increase the potential for water absorption and dimensional movement, but might allow for some stress relaxation within the board. Surface roughness would tend to lower bond strength.

The two board types exhibited strikingly dissimilar relationships for most properties, as shown by the simple regression correlations in Tables 3, 4, and 5. Some of the differences are due to basic wood characteristics that were not measured, such as cell structure and strength properties. With most properties related to densification and internal bond, a point is reached beyond which further change has little effect. All rootboards had fairly high densification, and the degree of particle contact was great enough so that further densification improved bonds very little. Thus, in rootboards,

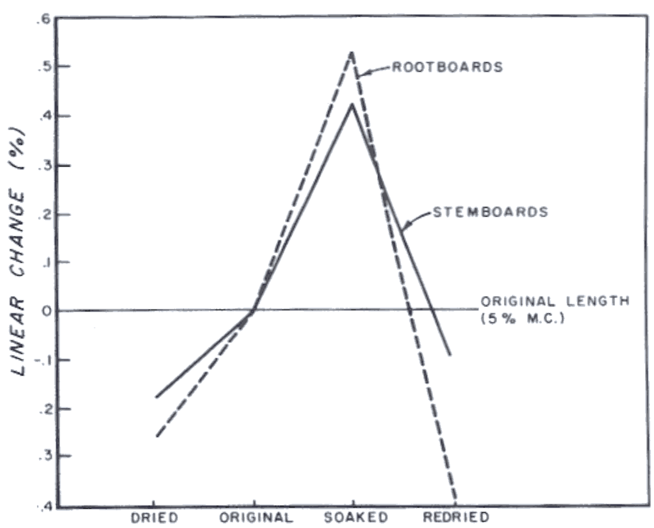

Figure 6. — Length changes of boards tested by VPS method. Drying change was almost one-third of total linear change. In rootboards, strips that had been soaked, then redried in an oven, were shorter than strips that were dried without prior soaking.

Table 3. — SIMPLE LINEAR CORRELATIONS (r)[1] FOR FLAKEBOARDS COMPRISED OF STEMWOOD AND ROOTWOOD (6-INCH-HIGH STUMP WITH TAPROOT).

	MOR		MOE		Internal bond	
	Stem	Root			Stem	Root
Wood specific gravity	....					
Board density	.65					
Densification ratio	.55		....	....	.44	....
MOR			.47	.86	.57	....
MOE	.47	.86			....	....
MOE/MOR	—.83	—.81			—.72	....
Nail withdrawal	....	.52		.58		.48

r ≥ 0.44 significant at 0.01 level; nonsignificance denoted by .....

Table 4. — SIMPLE LINEAR CORRELATIONS (r)[1] FOR THICKNESS STABILITY RELATIONSHIPS OF STEM AND ROOT FLAKEBOARDS.

	Thickness					
	Swell				Springback	
					Stem	Root
Wood specific gravity	....				—.66	
Densification ratio	.58		.56		.77	.44
Nail withdrawal	....	—.51		—.50		—.52
Internal bond	....	—.64		—.64		—.61
Moisture content (original)	....	.54		.54		.46
Moisture content (soaked)	....	.61		.60		.58
Thickness swell			.99	1.0	.88	.97
Thickness springback	.88	.97	.85	.97		
Linear drying Δ	....	—.44		—.45		

[1]Nonsignificance at 0.01 level denoted by ...

Table 5. — SIMPLE LINEAR CORRELATIONS FOR LINEAR STABILITY RELATIONSHIPS OF STEM AND ROOT FLAKEBOARDS.

	Linear					
	Swell				Redried length	
	Stem	Root			Stem	Root
MOR		—.65		—.65	....	....
MOE		—.65		—.65	....	....
MOE/MOR		.44		.44	.67	
Internal bond		....		....	—.74	
Linear swell			.94	.96	....	
Linear drying Δ		.49	.50	.72	....	—.55
Total Δ	.94	.96			....	—.50

[1]Nonsignificance at 0.01 level denoted by .....

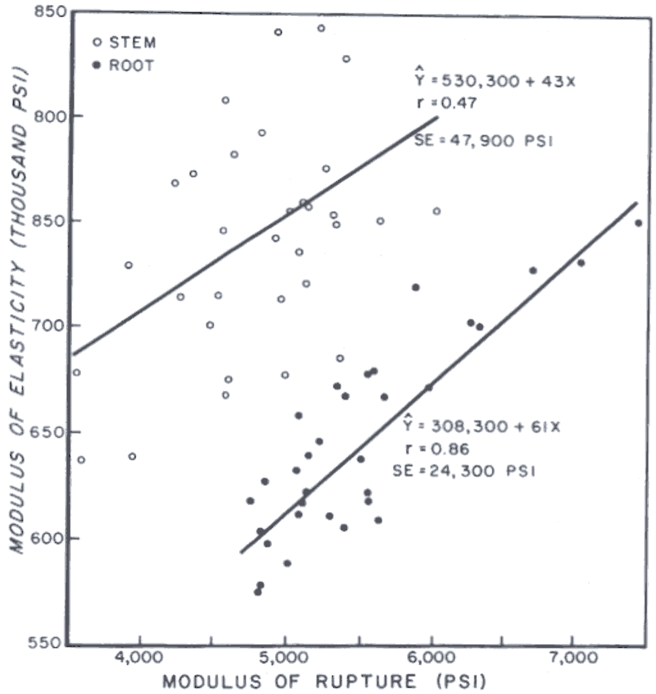

Figure 7. — Relationship of MOE to MOR for flakeboards made from stemwood and from the stump-taproot system. Here and in Figures 8, 9, 10, all equations are significant at the 0.01 level ($r > 0.44$ for individual board types and > 0.32 for all boards).

densification was not significantly related to most properties.

Because it adjusts for variation in board density, densification ratio gave stronger relationships with the various properties than did specific gravity of the original material (Tables 3 and 4). MOR of rootboards was strongly associated with MOE (Fig. 7), but in stemboards bending strength was better related to board density, internal bond, and densification ratio.

A strong relationship was found between internal bond and MOE/MOR ratio in stemboards; the correlation was even higher when all boards were considered, although in rootboards alone the relationship was not significant at the 0.01 level (Fig. 8). Correlations of internal bond with either MOE or MOR alone were much lower than for the combined factor. A similar situation was noted for other properties closely related to internal bond and MOE/MOR.

Rootboards with high nail-withdrawal resistance were stiffer and had higher bending strength, higher internal bond, and less thickness swelling and springback than rootboards with low nail-withdrawal values. In stemboards, nail-withdrawal increased with board density (r=0.50) but was not related to any other property.

In both wood types, thickness springback rose sharply with thickness swell and increased with densification (Fig. 9). In rootboards, thickness change, springback, and soaked moisture content declined as internal bond increased. In stemboards, however, these properties were not significantly related (0.01 level) to internal bond.

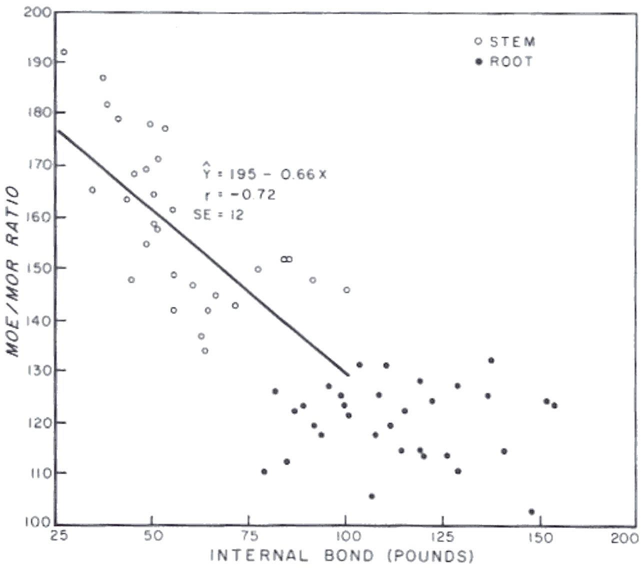

Figure 8 — Boards with high MOE/MOR ratios had low internal bond. For all boards, r = —0.82.

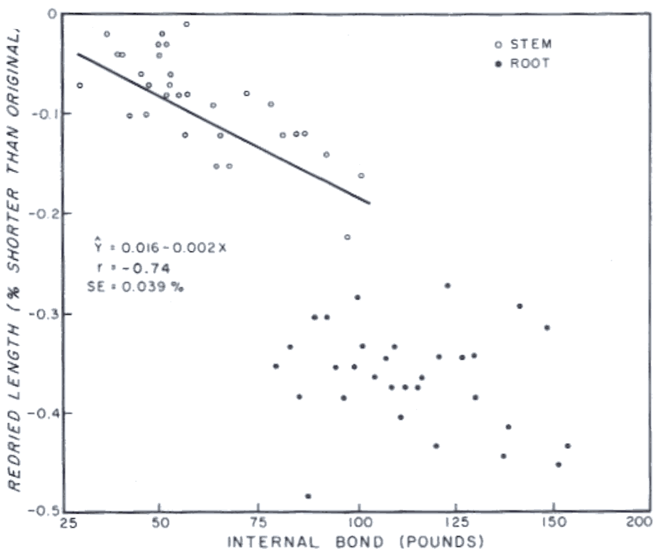

Figure 10. — Boards with high internal bond were shorter after soaking and redrying than boards with low internal bond. For all boards, the simple correlation coefficient was —0.82.

Linear swell in rootboards (unlike thickness changes) was negatively related to bending strength and stiffness, and was not related to internal bond (Table 5). In stemboards, linear swell was not significantly correlated with any other measured property; however, redried length after swelling was shorter in boards with high internal bond (Fig. 10). Redried length was also shorter in boards with low MOE/MOR ratio—a result consistent with the strong relationship observed between internal bond and MOE/MOR.

Because only a small portion of total thickness change was drying shrinkage, the relationship of this variable to other board properties was essentially the same as that of thickness swell alone.

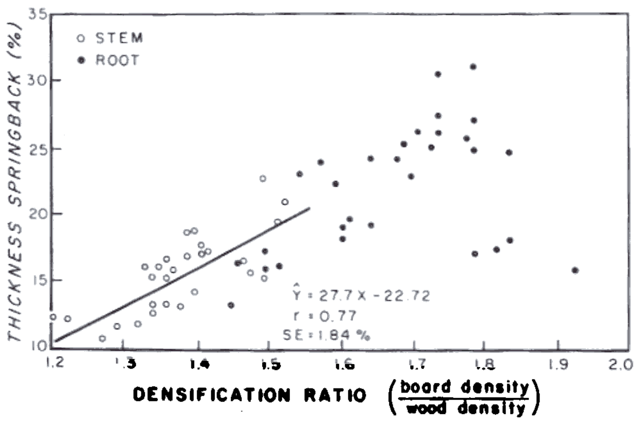

Figure 9. — Relationship of thickness springback to densification ratio. For all boards, r = 0.76.

Discussion

The lower specific gravity of rootwood was beneficially related to only two properties: bending strength was slightly greater, and internal bond was nearly double that of stemboards. All other strength properties were comparable. Rootboards were not as dimensionally stable as stemboards.

As furnish for particleboards, wood from stumps and taproots appears satisfactory, but flake cutting problems can be anticipated. Ingrown compressed dirt pockets, sometimes with stones, are a major hazard to cutting edges. A knifeless method of particle production, perhaps with partial preliminary breakdown to facilitate dirt removal, would be desirable.

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