PERFORMANCE OF PALLET PARTS RECOVERED FROM USED WOOD PALLETS

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ABSTRACT

The flexural modulus of elasticity (MOE), flexural modulus ofrupture (MOR), and density of used pallet parts were measured and compared to the same properties of new parts. Seventy-four percent of used pallet parts sampled were hardwoods, and 26 percent were softwoods. The average mixed hardwood parts were 41 percent stronger and 40 percent stiffer than the mixed softwood parts. The mixed eastern oaks were the most common species sampled, and reflected the relative volume of these species used to make new pallets. The average dry used oak deckboards were 47 percent stronger and 23 percent stiffer than green new oak parts, due primarily to the difference in moisture content (MC). However, when adjusted to the same MC, the predicted average MOR and MOE of used oak deckboards was 15 and 21 percent less, respectively, than new oak deckboards. Without sortation, used parts dimensions were more variable than that of new parts. Material property values for various groupings of used parts were developed for use in future versions of the Pallet Design System program dealing with repaired and rebuilt pallets.

There were an estimated 411 million new pallets manufactured in the United States in 1995 (12). According to ASME MH1 Part 2 (2), the most common pallet style in North America is the 48- by 40-inch, 3-stringer, partial 4-way, non-reversible, Grocery Manufacturers of America (GMA) type pallet **(Fig. 1).** In 1995, an estimated 171 million pallets were received by pallet recyclers for repair, reuse, or recycling (3). Many pallets are repaired and reused, but some retrieved pallets are odd sizes, are badly damaged, or otherwise unmarketable. Many of these unmarketable pallets, however, contain usable parts that may be recovered using specialized pallet disassembly equipment. In 1995, 18 percent of these retrieved pallets were disassembled for the usable wood parts (3). These recovered parts are then used as the raw material for two products: repaired pallets and reassembled pallets. Recovered pallets that are to be reused often contain broken boards that need replacement. Used boards recovered from other pallets are utilized for this repair. Used parts may also be utilized to build reassembled pallets, which are pallets assembled entirely or partly of used parts recovered from other pallets. Despite the widespread use of used pallet parts, no study of the properties of used parts has been conducted.

Several researchers (4-7,10) have studied the performance of new pallet parts. These studies include measurement of the flexural modulus of rupture (MOR), flexural modulus of elasticity (MOE), specific gravity (SG), moisture content (MC), grade mix, and dimensional variation for various wood species used to manufacture new wood pallets. These data have been used in the development of the Pallet Design System (PDS) (9). PDS is a reliability-based computer-aided design procedure for wood pallets. PDS helps pallet designers develop pallets that perform efficiently during material handling. PDS is recognized as a standard pallet design method in ASME MH1 Part 3 (2) and can be used to design pallets manufactured of lumber, plywood, and OSB decks. Currently, PDS is used to predict the performance of pallets manufactured with new wood components only.

New wood pallet parts are grouped into 13 domestic species classes (2) **(Table 1).** Each class includes species that exhibit similar flexural MOR and MOE. These species classes are based on bending tests of new pallet parts (4-7,

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Figure 1. — Photograph of a typical 48- by 40-inch, 3-stringer, partial 4-way, non-reversible, GMA-style pallet.

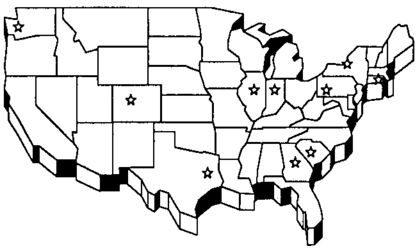

Figure 2. — Used pallet parts sampling locations.

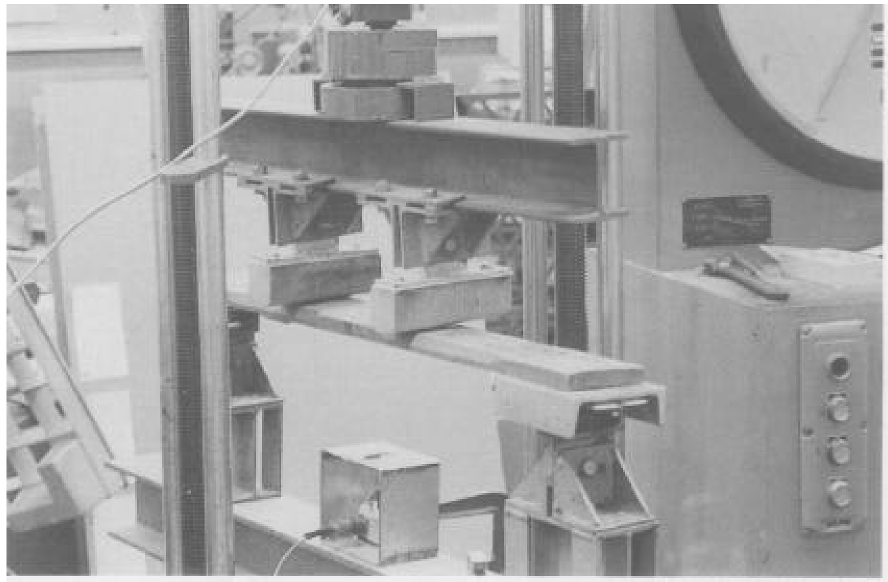

Figure 3. — Test set-up used to measure flexural strength and stiffness of used pallet parts.

TABLE 1. — Current wood species classes for new pallet parts (2).

Species class	Species included in the class
1	Hickory, yellow birch, sweet birch, sugar maple, red maple, black maple, green ash, white ash, rock elm, slippery elm, American beech, black locust, black cherry, tanoak, dogwood, persimmon, eucalyptus
2	Bigleaf maple, Oregon ash
3	Sweetgum, tupelo, paper birch, black ash, pumpkin ash, hackberry, sycamore, silver maple, striped maple, magnolia
4	Oregon white oak, California black oak, cascara, chinquapin, myrtle, madrone
6	Red alder
7	Aspen, catalpa, buckeye, butternut, American basswood, cottonwood
11	Douglas-fir, western larch
12	Western hemlock, mountain hemlock, California red fir, grand fir, noble fir, Pacific silver fir, white fir
13	Spruces (all), pines (all but loblolly, longleaf, shortleaf, and slash), subalpine fir, balsam fir, eastern hemlock, western redcedar, redwood
14	Cedars (all but western redcedar)
21	Eastern red and white oaks
22	Loblolly pine, longleaf pine, shortleaf pine, slash pine
29	Yellow-poplar

10). ASME MH1, Part 3 (2) also contains recommended pallet part quality grades. These are based on a grading procedure developed by Wallin and Frost (13). Studies of new pallet parts have determined the typical pallet part grade mixes used by pallet manufacturers in the United States. Most pallet designers using PDS use grade mixes documented by these studies. There is no corresponding documentation, however, of the mechanical properties, physical properties, and grade mixes of used parts. Before tools such as PDS can be used to design pallets containing used lumber, the physical and mechanical properties, species groupings, and grade mixes must be determined.

RESEARCH OBJECTIVES

The objectives of this research were to determine the species mix, grade distribution, physical characteristics, and mechanical properties of used wood pallet parts intended for the repair and reassembly of pallets. In this research, the flexural strength and stiffness of new and used wood pallet parts were compared. Material properties for practical groupings of used pallet parts were developed for use in PDS for predicting the performance of repaired and reassembled wood pallets.

TEST MATERIALS AND METHODS

Samples for this study were randomly selected from the inventory of used cut-to-size stringers and deckboards ready to be used in the repair and remanufacture of pallets. The used pallet parts were sampled from 10 pallet repair facilities. Mills were selected based on concentrations of the pallet recycling industry within geographic areas. **Figure 2** shows the geographic location of each mill sampled. Parts were randomly selected from inventory. The number and size of parts varied at each location due to availability. A total of 255 nominal 2- by 4- by 48-inch unnotched stringers, 246 nominal 1- by 4- by 40-inch deckboards, and 221 nominal 1- by 6- by 40-inch deckboards were collected and tested. These are the three component sizes used in the GMA-style pallet shown in **Figure 1.** Although the stringers would be notched prior to use in a GMA-style pallet, they are tested unnotched so that the MOR and MOE can be calculated.

Parts were shipped to the Virginia Tech William H. Sardo, Jr. Pallet and

TABLE 2. — Wood species and species group distribution among all used pallet parts sampled.

Species	Scientific name	Percentage of used parts sampled
Mixed eastern oaks	Quercus spp.	36.6
Southern yellow pine	Pinus spp.	15.9
Hard maple	Acer spp.	14.0
Spruce	Picea spp.	6.2
Yellow-poplar	Liriodendron tulipifera	4.5
Cottonwood	Populus spp.	3.1
Hickory	Carya spp.	2.7
Elm	Ulmus spp.	2.4
Douglas-fir	Pseudotsuga menziesii	1.9
Black cherry	Prunus serotina	1.9
Black gum	Nyssa sylvatica	1.6
Hemlock	Tsuga spp.	1.7
Aspen	Populus spp.	1.3
Red alder	Alnus rubra	1.2
American beech	Fagus grandifolia	1.0
American basswood	Tilia americana	0.9
Ash	Fraxinus spp.	0.7
Birch	Betula spp.	0.7
Soft maple	Acer spp.	0.6
Black locust	Robinia pseudoacacia	0.4
Eastern white pine	Pinus strobus	0.3
Buckeye	Aesculus spp.	0.1
Sweetgum	Liquidambar styraciflua	0.1
Other		0.2
Total		100.0

Container Research Laboratory for inspection and evaluation. Pallet part width and thickness were measured to the nearest 0.001 inch at the midpoint along the part length. Each pallet part was graded according to the procedure described in Wallin and Frost (13).

All parts were tested to destruction in third-point bending using the procedures outlined in ASTM D 198-84 (1). The test apparatus used was a Tinius-Olsen Universal test machine. The test set-up is shown in **Figure 3.** Deckboards and stringers were tested using spans of 36 and 44 inches, and using crosshead speeds of 3.2 and 1.1 inches per minute, respectively. These speeds were faster than the ASTM standard test rate and were necessary due to the large number of parts tested. McLeod (8) has developed adjustments for pallet part MOR and MOE from these accelerated rates. After testing, samples were cut from each board to determine MC and SG using the ovendry method. The MINITAB (11) statistical analysis program was used in the evaluation of the test results.

RESEARCH RESULTS AND DISCUSSION

SPECIES OF USED WOOD PALLET PARTS

Table 2 contains the common names, scientific names, and the percentage of each species or species group of the used pallet parts sampled. The combined red and white oaks *(Quercus* spp.) were the most common species, representing more than one-third of the used parts collected. The southern yellow pines *(Pinus* spp.), the hard maples *(Acer* spp.), and the spruces *(Picea* spp.) represented 15.9, 14, and 6.2 percent, respectively, of the parts collected. Many of the spruces were grade-marked as "SPF" (spruce-pine-fir). All other species represented less than 5 percent each of the sampled used parts. A small percentage of parts were listed as "other" and were likely not indigenous to North America. Seventy-four percent of the parts sampled were hardwoods (angiosperms) and 26 percent softwoods (gymnosperms).

A 1995 study conducted by the Center for Forest Products Marketing and Management (12) determined that mixed eastern oaks were the most common new parts used by the pallet and container industry. That study found that 72 percent of new pallet lumber was hardwood and 28 percent was softwood. This corresponds closely with the 74 percent hardwood and 26 percent softwood found in the used parts collected for our study.

USED PALLET PART SPECIES DISTRIBUTION BETWEEN SAMPLING SITES

It is often not economical to ship new pallet lumber or parts long distances; therefore, new pallets are typically manufactured of species found within the region that the pallets are manufactured. New pallet manufacturers in the eastern United States commonly use wood species in classes 1, 3, 7, 13, 21, 22, and 29 **(Table 1).** In the western United States, species in classes 6, 11, 12, and 13 are more commonly used for pallet manufacture. Used parts are recovered from pallets shipped throughout the country; therefore, the distribution of species may not be subject to regional influences.

Table 3 contains the percentage of used pallet parts within 9 of the pallet part species classes for each of the 10 repair mills sampled. The other four species classes were not found in the used parts sampled. For 9 of the 10 mills sampled, the combined dense hardwoods and mixed eastern oaks (Classes 1 and 21) were the majority of the parts sampled. The Pennsylvania mill was the exception, using a large percentage of southern yellow pine (Class 22). All 10 mills sampled contained more hardwood parts (Classes 1, 3, 6, 7, 21, 29) than softwood parts (Classes 11, 13, 22). The predominance of dense hardwoods was even true for mills located in the western United States, far from the source of these species of timber. This reflects the transcontinental shipment of pallets and may also reflect that the dense hardwoods are more durable, and therefore more likely to withstand the rigors of shipping and handling environments and disassembly equipment. There appears to be no regional influences on the species mix of used pallet parts. Pallet manufacturers may assume similar species mixes of used parts.

VARIATION OF USED PALLET PART SIZES

New pallet parts are sawn to a variety of target dimensions depending on the new pallet specification. The used parts sampled during this study reflect the wide variation of target dimensions produced by new pallet manufacturers. The results of these measurements of used pallet parts are given in **Table 4** for each nominal size.

Variation in deckboard thickness was approximately three times that of board width. Variation in stringer width was almost three times that of stringer height. These variations result because new pallet manufacturers alter the thickness of deckboards and widths of stringers when producing parts. The raw materials from which new pallet parts are manufactured are cants and lumber. The widths of these raw materials are relatively constant, and this determines deckboard width and stringer height.

These dimensional variations of used parts are similar to those observed by McLain (7) when sampling new oak pallet parts from 10 mills in the eastern United States. However, during new pallet manufacture, parts of different actual target thickness are not mixed within a pallet at assembly. Companies using reclaimed used parts to reassemble or repair wood pallets must be as diligent in segregating parts by size. Variation of component sizes within a pallet will affect pallet performance. Without sortation, accurately predicting pallet performance will be difficult. Excessive variation of deckboard thickness within a pallet deck also creates stress concentrations for products supported by the uneven surface. Packaging designers must increase the strength of packaging to resist stress concentrations imposed by the uneven deck surfaces of used pallets. According to ASME MH1 Part 10 (2), the difference in deckboard thickness within a pallet deck cannot exceed 0.25 inch. The range in thickness represented by the sampled used parts is two to three times this limit. Therefore, the dimensional variation of used pallet parts should be reduced by dimensional sorting.

GRADE DISTRIBUTION OF USED PALLET PARTS

All parts were visually graded for quality using the Grade 2 & Better, Grade 3, Grade 4, or below-grade descriptions developed by Wallin and Frost (13). New pallet manufacturers often choose to exclude below-grade components to produce stronger, more durable multiple-use pallets.

The relationship between used pallet part size, species, and grade is shown in **Table 5.** In general, there was very little difference in the grade mix of the stringers and deckboards inspected. Used hardwood parts contained more 2 & Better or high quality, and fewer below-grade parts, compared to used softwood parts. The raw material for most hardwood pallet material is low-grade cants and 3A and 3B lumber, while many softwood parts are resawn from economy and utility grade dimension lumber. Previous part studies have determined that the typical grade mix for new hardwood pallet parts being used in pallets is 48 percent 2 & Better, 31 percent Grade 3, 13 percent Grade 4, and 8 percent below-grade material (8). This is a default grade mix used in the PDS pallet design system. The used hardwood pallet parts exhibited a similar grade mix. Both new and used softwood parts, however, contained less high-grade and more below-grade parts than typically used in new hardwood pallet

TABLE 3. — The distribution of pallet parts by species classes between the 1O sampling locations.

Mill location	Percent of used pallet parts within each PDS species class[a]								
	1	3	6	7	11	13	21	22	29
Texas	12	6	4	6	4	8	46	4	10
Georgia	25	4	--	10	--	--	46	12	3
South Carolina	14	6	--	2	6	--	30	36	6
Pennsylvania	5	9	3	5	3	--	31	44	--
Rhode Island	48	4	--	2	--	--	38	2	6
New York	30	--	6	--	4	32	14	6	8
Illinois	43	2	--	8	--	6	33	2	6
Indiana	29	--	--	2	--	--	62	--	7
Washington	20	4	--	7	1	33	20	12	3
Colorado	22	--	--	15	2	--	49	12	--
Average	23	4	1	5	2	8	37	15	5

[a] Other PDS species classes indigenous to the United States, such as 2,4,12, and 14, contained an insignificant number of specimens.

TABLE 4. — The variation of used pallet part dimensions sampled from 10 locations throughout the United States.

Pallet part nominal size	No.	Dimension	Average dimension	Coefficient of variation	Range of measured dimensions
			(in.)	(%)	(in.)
1- by 4-inch deckboards	246	Width	3.601	6.3	2.398 to 4.411
		Thickness	0.649	15.5	0.361 to 0.954
1- by 6-inch deckboards	221	Width	5.565	5.0	4.188 to 6.086
		Thickness	0.639	15.4	0.375 to 1.079
2- by 4-inch stringers	255	Width	1.360	9.8	0.928 to 1.709
		Height	3.488	3.5	3.116 to 3.875

manufacture. The PDS default grade mix can be utilized for used hardwood parts. A PDS default grade mix for new and used softwood species should reflect the lower grade quality of these softwood parts.

COMPARATIVE FLEXURAL STRENGTH AND STIFFNESS OF USED AND NEW PALLET PARTS

For comparison, the physical and mechanical properties of new (green and air-dried) and used eastern oak pallet parts are shown in **Table 6.** New, green and air-dried, oak pallet parts were evaluated in previous studies in 1986 (7) and 1998 (5). The average MOR and MOE of used oak pallet parts were greater than that of new green parts. With the exception of deckboard MOR, the average MOR and MOE of new and used dry parts were not significantly different.

The strength and stiffness of lumber typically increases as it dries below fiber saturation point (25 to 30% MC). The average MC of the wood in used pallets and pallet parts was 11 to 12 percent. New air-dried parts had been carefully conditioned to a target 17 to 18 percent MC, which simulates a typical air-dried pallet at initial sale. **Table 6** also contains the predicted average deckboard and stringer MOR and MOE for corresponding new parts at the 11 to 12 percent MC of used parts. These predicted values were based on adjustments of the MOR and MOE of new parts at 17 to 18 percent using the procedures described in the *Wood Handbook* (14). There is very little predicted difference in strength and stiffness between new and used stringers at the same MC. However, the average new oak deckboards are predicted to be about 15 percent stronger and 21 percent stiffer than the used parts. This difference is likely due to the consistent presence of two or three nail holes in the middle of each used deckboard. The disassembly of used 3-stringer pallets **(Fig. 1)** will result in salvaged deckboards with three sets of nail holes: one set at each end and one set in the middle. These holes in the middle of the used deckboards appear to act as defects, and this is the region of maximum bending moment during testing. **Figure 4** is a photograph of a typical bending failure of a used deckboard. As illustrated, the bending failure is often at the location of the middle set of nail holes. **Figure 5** shows typical nail holes in both used stringers and deckboards. The nail holes along the top and bottom edge of the used stringers contain stubs and do not seem to significantly affect average bending strength and stiffness.

The flexural properties of used oak parts were much more variable than that of both green and air-dried new oak parts. The greater variation within used parts may also be a result of holes from pallet fasteners, primarily nails.

No other species of used parts contained an adequate number of samples to justify comparison with new pallet part properties. Therefore, until better data are available, when developing PDS species classes for used parts, it is recommended that the relative difference between new and used oak properties be used as an adjustment factor for all other PDS species classes. Several PDS classes incorporate both green and dry material property values, and the av-

TABLE 5. — The effect of pallet part size and species group on the grade distribution of usedpallet parts.

Part size	Replicates	Pallet part grade distribution[a] 2 & Better	3	4	Below grade
		(%)			
Used 1 by 4 deckboards	246	38	35	20	7
Used 1 by 6 deckboards	221	32	35	23	10
Used 2 by 4 stringers	255	37	33	19	12
Used hardwood parts	463	41	32	20	7
Used softwood parts	171	25	37	25	13
Previous grade studies of new pallet parts					
Southern yellow pine deckboards and stringers, 1997[b]	750	30	30	18	22
Mixed hardwood pallet parts tested in 1985[c]	17,817	48	31	13	8

[a] The grade specifications used were developed by Wallin and Frost (13).
[b] Clarke, McLeod, and White (4).
[c] McLeod (8).

TABLE 6. — Average flexural strength and stiffness of new[a] and used eastern oak pallet parts.

Pallet part condition	Replicates	Moisture content Average	Moisture content COV	Modulus of rupture Average	Modulus of rupture COV	Modulus of rupture Tukey's distribution[b]	Modulus of elasticity Average	Modulus of elasticity COV	Modulus of elasticity Tukey's distribution[b]
		(%)		(psi)	(%)		(million psi)	(%)	
Used oak deckboards	147	11	21	9,606	31	A	1.695	39	A
New oak deckboards - air-dry	105	18	7	8,499	23	B	1.679	26	A
New oak deckboards - green	110	61	20	6,516	23	C	1.374	29	B
New oak deckboards, 11% MC (predicted)[c]				11,086			2.052		
Used oak stringers	57	12	22	8,464	45	A	1.428	36	A
New oak stringers - air-dry	52	17	6	7,988	36	A B	1.276	25	A B
New oak stringers - green	50	71	12	6,804	29	B	1.108	26	B
New oak stringers, 11% MC (predicted)[c]				8,830			1.399		

[a] New oak parts were previously tested (7).
[b] Average observations with the same capital letter are not statistically different.
[c] These are predicted values based on adjustments of the new air-dry measurements to the equivalent MC of the corresponding used parts using the procedures described in the Wood Handbook, Chapter 4 (14).

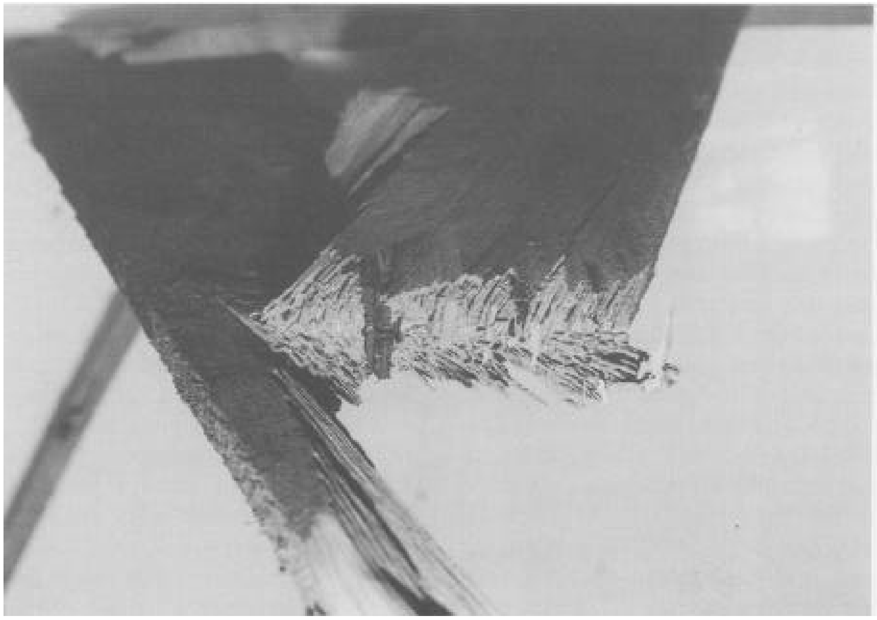

Figure 4. — Typical bending failure of a used pallet deckboard associated with the middle set of nail holes.

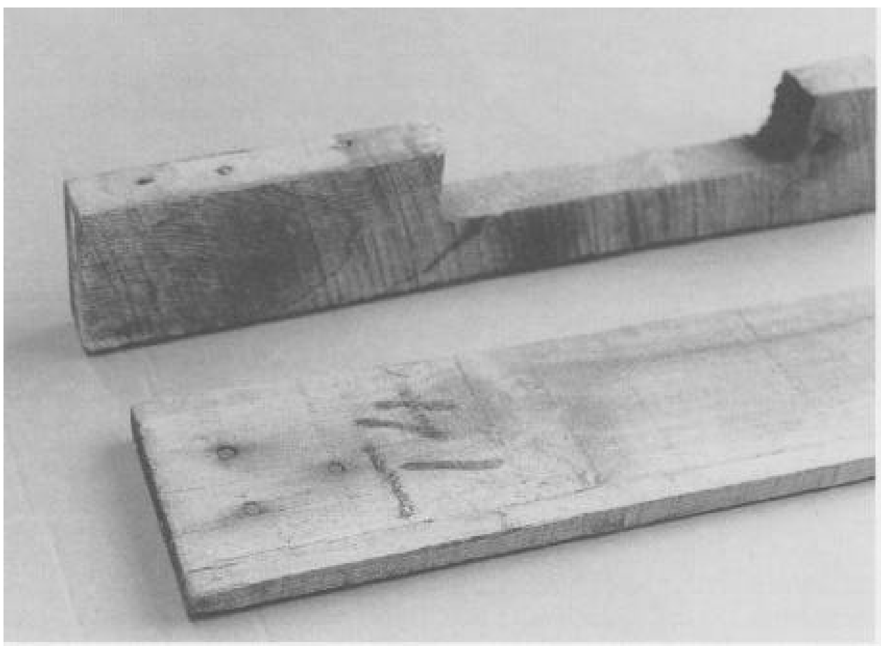

Figure 5. — Typical nail holes and nail stubs in used deckboards and stringers.

erage dry values may be used if the higher variation inherent to used parts is incorporated.

PALLET PART SIZE EFFECTS ON MATERIAL PROPERTIES

Table 7 contains the mechanical properties of used pallet parts segregated by nominal size. A Tukey's comparison indicates that there were no significant differences between used 4-inch and used 6-inch deckboards. However, the average MOR and MOE of deckboards was greater than that of used unnotched stringers. There was no significant difference in density or MC between deckboards and stringers.

Previous studies (4-7,10) have investigated the effect of pallet part size on the flexural MOR and MOE of new parts. These studies confirm that, within a species, there are no significant differences between new 4-inch- and new 6-inch-wide deckboards, but that flexural MOR and MOE of new pallet deckboards were greater than that of stringers. Therefore, within any proposed classification of used pallet parts, separate material property values for deckboards and stringers are recommended.

GROUPING USED PALLET PARTS FOR USE IN THE PDS PROGRAM

Within PDS, new pallet parts are currently grouped into 13 species classes (groups). Species selection is a major factor in designing pallets. Sawmills supplying pallet manufacturers typically segregate species, and regional availability is determined by growing ranges for different tree species. Therefore, during new pallet fabrication, species selection is controlled. However, for pallet repair and remanufacturing with used parts, segregating by individual species is not practical given the weathered condition of the parts and difficulty of species identification. As reported earlier, used components are comprised of parts from throughout the

TABLE 7. — Effect of component size on the mechanical properties of used pallet parts[a]

		Modulus of rupture			Modulus of elasticity		
Nominal size	Replicates	Average	COV	Tukey's distribution[b]	Average	COV	Tukey's distribution[b]
		(psi)	(%)		(million psi)	(%)	
1- by 4-inch deckboards	246	8,539	38.6	A	1.617	40.2	A
1- by 6-inch deckboards	221	8,924	36.4	A	1.544	41.3	A
2- by 4-inch stringers	255	7,253	47.8	B	1.149	43.3	B

[a] The average density and MC is not statistically different between stringers and the two deckboard sizes.
[b] Average observations with the same capital letter are not statistically different.

TABLE 8. — *Average flexural properties for various groupings of used pallet deckboards.*

Grouping	% of sample	Modulus of rupture		Modulus of elasticity		Specific gravity	
		Average	Tukey's distribution[a]	Average	Tukey's distribution[a]	Average	Tukey's distribution[a]
		(psi)		(million psi)			
All species	100	8721 (38)[b]	--	1.582 (41)	--	0.603 (20)	--
All hardwoods	76	9388 (34)	A	1.646 (38)	A	0.640 (17)	A
Softwood	24	6662 (42)	B	1.393 (35)	B	0.488 (19)	B
Oak	33	9606 (31)	A	1.695 (39)	A	0.702 (9)	A
All other hardwood species	42	9223 (36)	A	1.606 (37)	A	0.593 (18)	B
Softwood	24	6662 (42)	B	1.393 (35)	B	0.488 (19)	C

[a] Average observations with the same capital letter are not statistically different.
[b] Numbers in parentheses are the coefficients of variation in percent.

TABLE 9. — *Average flexural properties for various groupings of used pallet stringers.*

Grouping	% of sample	Modulus of rupture		Modulus of elasticity		Specific gravity	
		Average	Tukey's distribution[a]	Average	Tukey's distribution[a]	Average	Tukey's distribution[a]
		(psi)		(million psi)			
All species	100	7253 (48)[b]	--	1.149 (43)	--	0.596 (24)	--
Hardwood	65	8159 (46)	A	1.363 (36)	A	0.647 (19)	A
Softwood	35	6337 (46)	B	0.906 (49)	B	0.458 (20)	B
Oak	35	8464 (45)	A	1.428 (36)	A	0.691 (10)	A
All other hardwood species	30	7765 (48)	A B	1.283 (36)	A	0.589 (25)	B
Softwood	35	6337 (46)	B	0.906 (49)	B	0.458 (20)	C

[a] Average observations with the same capital letter are not statistically different,
[b] Numbers in parentheses are the coefficients of variation in percent.

country (and overseas), and not from regionally segregated sources. Therefore, most used pallet parts will not be segregated by species. Some companies repairing pallets try to separate softwood from hardwood, or oak from other hardwoods, but until technology is available that efficiently separates species or density, little segregation beyond hardwood and softwood is likely to occur.

Tables 8 and **9** list the material properties for mixed oak, all other hardwoods, and softwoods for deckboards and stringers for potential use in a future version of PDS. For both deckboards and stringers, the mean MOR, MOE, and SG of mixed hardwoods were significantly greater than that of softwoods. Likewise, mixed oak part properties were significantly greater than that of softwoods, but not all other combined hardwoods. In general, the levels of property variation decrease as parts are segregated into more classes. The average flexural properties of oak are not significantly different from the other mixed hardwoods. This indicates that the separation of oak from the other hardwoods is of little value for used pallet parts. This confirms that the practical sortation of used pallet parts should be hardwoods from softwoods. Sortation by component size is also necessary.

Conclusions

- The species mix and relative volume of each species of used pallet parts sampled is very similar to the mix and volume of species used to assemble new pallets. The used part species mix within each region contains species from all regions, reflecting the transcontinental movement of pallets.
- The variation of used pallet part deckboard thickness and stringer width is two to three times that of new parts in assembled pallets, indicating dimension sorts will be necessary prior to the use of salvaged parts.
- The grade of quality of the hardwood used parts was better than that of used softwood parts and typical of the quality used to manufacture new hardwood pallets. Therefore, current grade mixes used to design new hardwood pallets will be applicable to hardwood pallets containing used parts. The grade mix of softwood parts contained a lower percentage of 2 & Better parts and a higher percentage of below-grade parts.
- The average flexural strength and stiffness of used pallet parts (11 to 12% MC) of the same species and grade is similar to new air-dried parts at 17 to 18 percent MC and is greater than new green parts due to the differences in MC. When adjusted to the same MC, the predicted average flexural strength and stiffness of the new deckboards is greater than that of used deckboards due to the presence of nail holes in the used parts. Because of these nail holes, the flexural strength and stiffness of used deckboards and stringers varies more than new deckboards and stringers. This variation should be considered when assigning structural property values to used parts for designing pallets using PDS.
- The most practical and effective grouping of used parts, by species, will be the separation of hardwood parts from softwood parts. Sorting used parts by species is difficult, and given the relative differences in flexural properties, would not significantly improve pallet performance prediction estimates.

- Performance estimates of pallets containing used parts should reflect the higher levels of variation of component flexural strength, stiffness, and dimensions.

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