PERFORMANCE OF PALLET NAILS AND STAPLES IN 22 SOUTHERN HARDWOODS

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WOOD RESEARCH AND WOOD CONSTRUCTION LABORATORY
PALLET AND CONTAINER RESEARCH CENTER

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BLACKSBURG, VIRGINIA JUNE, 1976 NO. 145

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ABSTRACT

The effectiveness of pointless, helically threaded, hardened-steel, 3 by 0.120-inch, pallet nails with umbrella heads and 2½-inch, 15-gauge, 7/16-inch crown, plastic-coated, pallet staples in 22 hardwoods grown on southern pine sites was determined on the basis of tests on 522 joints. Specific average performance values were derived from the test data for the tested joints made of, and representative for, these 22 hardwood species.

ACKNOWLEDGMENTS.—This study was performed under the auspices of the Pallet and Container Research Center of Virginia Polytechnic Institute and State University in cooperation with the USDA Forest Service's Southern Forest Experiment Station, which provided supporting funds for this project. Green logs and cants of the 22 hardwood species were made available by the Southern Forest Experiment Station, the Virginia Division of Forestry, and the Universitys' Reynolds Homestead Research Center. The pallet nails used for this study were provided by Philstone Nail Corporation of Canton, Massachusetts. The pallet staples and stapling gun used were manufactured by Senco Products of Cincinnati, Ohio.

Credit is due to Dr. Peter Koch, Project Leader, Forest Products Utilization Branch, Southern Forest Experiment Station, and Dr. Walter B. Wallin, Market Analyst, Forest Products Marketing Laboratory, Northeastern Forest Experiment Station, USDA Forest Service, for their active support and valuable suggestions in connection with this project.

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The 22 southern hardwoods included in this study are green and white ash, American and winged elm, hackberry, mockernut hickory, red maple, eleven oaks (black, blackjack, cherrybark, laurel, northern red, post, scarlet, shumard, southern red, water, and white oak), sweetbay (magnolia), sweetgum, black tupelo, and yellow poplar. These species are said to comprise more than 95 percent of the volume of southern hardwoods grown on southern pine sites. Table I provides information on the approximate percentage volume of

TABLE I

Twenty-Two Major Hardwood Species Grown on Southern Pine Sites

Hardwood Species Investigated	Volume in Per[b]	Specific Gravity[c]	Species Graded[d]	Source of Logs or Costs SFES[e]	VDF[f]	VPI&SU[g]
Sweetgum (Liquidambar styraciflua L.)	21	0.448	2	---	×	---
Hickory, true (Carya spp.)[a]	10	0.619	1	---	---	×
Black tupelo (Nyssa sylvatica Marsh.)	9	0.502	2	---	---	×
Post oak (Quercus stellata Wangenh.)	9	0.660	1	---	×	---
Southern red oak (Q. falcata Michx.)	9	0.609	1	---	×	---
Water oak (Q. nigra L.)	8	0.567	1	×	---	---
White oak (Q. alba L.)	8	0.673	1	---	---	×
Yellow-poplar (Liriodendron tulipifera L.)	4	0.397	2	---	---	×
Sweetbay (Magnolia virginiana L.)	3	0.437	2	×	---	---
Black oak (Q. velutina Lam.)	3	0.620	1	---	---	×
Cherrybark oak (Q. falcata var. pagoecefolia Ell.)	2	0.633	1	×	---	---
White ash (Fraxinus americana L.)	2	0.582	1	---	---	×
Green ash (F. pennsylvanica Marsh.)	2	0.561	1	---	×	---
Red maple (Acer rubrum L.)	1	0.496	2	---	---	×
American elm (Ulmus americana L.)	1	0.536	1	✓	---	---
Winged elm (U. alata Michx.)	1	0.623	1	×	---	---
Hackberry (Celtis occidentalis L.)	1	0.525	1	---	×	---
Northern red oak (Q. rubra L.)	1	0.597	1	---	---	×
Scarlet oak (Q. coccinea Muenchh.)	1	0.622	1	---	---	×
Shumard oak (Q. shumardii Buckl.)	1	0.625	1	×	---	---
Laurel oak (Q. laurifolia Michx.)	1	0.583	1	×	---	---
Blackjack oak (Q. marilandica Muenchh.)	1	0.638	1	---	×	---

a) Mockernut hickory (Carya tomentosa) was selected for test purposes.
b) Approximate percentage volume of the 22 hardwood species growing on southern pine sites.
c) Stemwood specific gravity based on green volume and oven-dry weight of trees 6 inches d.b.h.
d) Pallet species-grade classification.
e) Southern Forest Experiment Station of U.S. Forest Service.
f) Virginia Division of Forestry
g) Virginia Polytechnic Institute and State University.

* Prepared for presentation at the June 3d, 1976, Session of the Annual Pallet and Container Manufacturing and Sales Promotion Clinic of the National Wooden Pallet and Container Association at Queen Elizabeth Hotel in Montreal, Quebec, Canada, June 28-30, 1976, and at the July 15, 1976, Session on "Mechanical Fastening of Wood" during the 30th Annual Meeting of the Forest Products Research Society at the Four Seasons Sheraton Hotel in Toronto, Ontario, Canada, July 11-16, 1976.

these species and their stemwood specific gravity (based on green volume and oven-dry weight of trees of 6 inches d.b.h.). This table also indicates the pallet species-grade classification and the sources from which the green color-coded logs and cants were received.

All of these species have potential for use as pallet lumber. Some of them have been given preference for pallet manufacture. The use of others has been avoided mainly because of insufficient information on their performance in pallets. It is the purpose of this study to provide such information based on the static pallet deckboard-stringer separation resistance by such fasteners as are commonly used for pallet assembly.

The assembled joints consisted of 13/16 by 1½ by 6-inch deckboards crossing nominal 2 x 4 stringers. The oven-dry specific gravity and moisture content at test were determined for every deckboard and stringer used. The fastener spacing in the stringers was 3-inches and the minimum end spacing was 3 inches.

The nails used for deckboard-stringer joint assembly were pointless, helically threaded, hardened-steel, 3 by 0.120-inch, Philstone, pallet nails (VPI&SU No. 1785), having four helical flutes, a 63° thread angle, an 0.136-inch (0.132" to 0.138") thread-crest diameter, a ⅞-inch clearance, and an 0.316-inch diameter, flattened, thin-rimmed, umbrella head. These nails had a Mibant angle ranging from 12 to 25 degrees, with an average of 16 degrees; hence, were classified as "tough hardened-steel nails". They were hammer-driven, one per joint.

The staples used for deckboard-stringer joint assembly were 2½-inch long, 15-gauge, semi-flat (0.067 x 0.073-inch), 7/16-inch crown, galvanized, Sencote, pallet staples (VPI&SU Nos. 1370, 1369, and 1732), provided with a plastic-polymer coating along their legs from the tips of their short symmetrical chisel points to 1 3/16-inch from these tips. These staples were driven with a Senco Model M-III air-gun, one per joint.

As many as twelve replicate deckboard-stringer joints, each containing a single fastener, were assembled with green lumber and tested after several weeks of seasoning of the joints in the Laboratory at approximately 70° F. temperature and 50% relative humidity. The tests provided information on the static nail-head and staple-crown pull-through resistance in the deckboard and nail-shank and staple-leg withdrawal resistance in the stringer. The tests were performed at a constant rate of motion of 0.100 inches per minute of the cross-head of the 600 and 3000-pound capacity Olsen Electomatic testing machine.

The detailed test data are presented in Appendix Table I. The average data are listed in Table II and shown in graphical form in the bar diagrams of Figs. 1 and 2.

The average oven-dry specific gravity of the deckboards of the 22 species ranged from 0.42 to 0.80, with an average of 0.61; and that of the stringers ranged from 0.43 to 0.81, with an average of 0.64. The oven-dry specific gravity ranges and averages of deckboards and stringers of each species are presented in Fig. 3.

The average moisture content of the deckboards of the 22 species during testing ranged from 8.0 to 12.1 percent, with an average of 10.2 percent; and that of the stringers ranged from 10.0 to 17.0 percent, with an average of 12.3 percent. The moisture content ranges and averages of the deckboards and stringers of each species are presented in Fig. 4.

As many as 149 (57%) of the 261 nail heads separated from the nail shanks during the determination of the delayed head pull-through resistance of the hardened-steel pallet nails and only 63 (24%) of the 261 staple crowns broke off one or two staple legs during the determination of the delayed crown pull-through resistance of the coated pallet staples.

TABLE II

Average Delayed Deckboard-Stringer Separation Resistance of 22 Hardwood Specie from Southern Pine Sites

Species	Spec. Grade	Test No.	Spec. Grav. Green Vol. Dry Weight	Test Oven-Dry Spec. Grav. Deckbd.	Stringer	Test Moisture Content Deckbd.	Stringer	Head Pull-Through Res. in Lb.	Shank Withdrawal Res. in Lb.	Fastener Failure	Crown Pull-Through Res. in Lb.	Leg Withdrawal Res. in Lb.	Fastener Failure	Staple vs. Nail C/H	L/S
Sweetgum	2	5	0.448	0.46	0.52	11.9	12.2	820	877	2 of 12	513	188	0 of 12	63%	21%
Mock. Hickory*	1	8	0.619	0.73	0.81	9.7	11.6	1311	1437	11 of 12	690	190	11 of 12	53%	32%
Black Tupleo	2	15	0.502	0.46	0.54	9.3.	10.6	922	923	1 of 12	575	175	0 of 12	62%	19%
Post Oak	1	2	0.660	0.73	0.78	10.7	15.6	1261	1317	7 of 12	543	226	1 of 12	43%	17%
Southern R. Oak	1	4	0.609	0.63	0.68	9.5	11.2	1083	1222	9 of 12	553	280	1 of 12	51%	23%
Water Oak	1	19	0.587	0.74	0.70	10.0	14.0	1274	1316	11 of 12	625	271	7 of 12	49%	21%
White Oak	1	11	0.673	0.76	0.62	12.1	16.3	1235	1482	4 of 12	624	286	6 of 12	51%	19%
Yellow Poplar	2	10 16	0.397	0.42	0.43	11.0	11.2	704	628	0 of 24	456	152	0 of 24	65%	24%
Sweetbay	2	23	0.437	0.44	0.50	10.3	10.6	845	998	3 of 12	463	160	2 of 12	55%	16%
Black Oak	1	7	0.620	0.80	0.76	10.3	13.2	1407	1420	11 of 12	715	296	6 of 12	51%	21%
Cherrybark Oak	1	20	0.633	0.65	0.68	9.9	15.3	1207	1096	10 of 12	627	374	3 of 12	52%	34%
White Ash	1	14	0.582	0.52	0.58	10.8	(10.5)	1215	1099	11 of 12	708	173	1 of 12	58%	16%
Green Ash	1	1	0.561	0.57	0.59	9.7	10.2	1298	1124	11 of 12	739	191	1 of 12	57%	17%
Red Maple	2	12	0.496	0.57	0.59	10.2	10.5	1092	1340	5 of 5	773	105	3 of 5	71%	8%
American Elm	1	21	0.536	0.53	0.56	10.8	10.6	986	1082	3 of 12	585	204	1 of 12	59%	19%
Winged Elm	1	18	0.623	0.68	0.68	9.5	10.0	1407	1369	11 of 12	811	191	9 of 12	58%	14%
Hackberry	1	3	0.525	0.49	0.56	10.4	10.6	1053	1087	5 of 12	545	120	0 of 12	52%	11%
North. Red Oak	1	13	0.597	0.60	0.70	8.0	13.2	1085	1522	10 of 12	609	538	0 of 12	56%	35%
Scarlet Oak	1	9	0.622	0.70	0.74	9.4	12.1	1198	1477	7 of 12	521	311	5 of 12	43%	21%
Shumard Oak	1	17	0.625	0.73	0.73	9.6	13.5	1248	1311	9 of 12	683	494	2 of 12	55%	38%
Laurel Oak	1	22	0.583	0.59	0.61	9.7	17.0	1091	1103	7 of 12	582	497	3 of 12	53%	45%
Blackjack Oak	1	6	0.638	0.69	0.74	11.4	11.5	1098	1123	1 of 4	570	227	1 of 4	52%	20%
Average		22	0.572	0.61	0.64	10.2	12.3	1129	1198	149 of 261	614	257	63 of 261	55%	22%
										57%			24%		
Average		22		100%	105%			100%	106%		100%	42%			

Serving as representative of the true hickories.

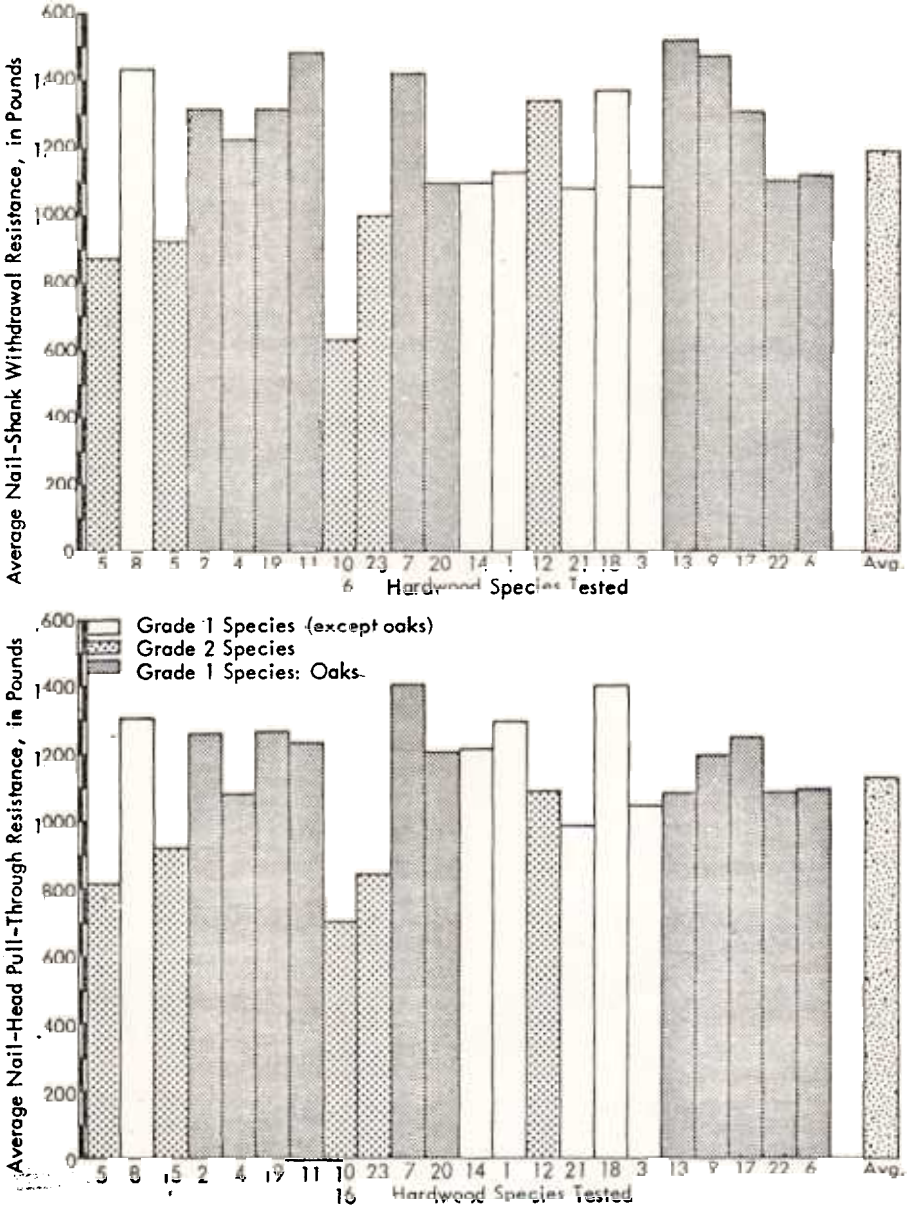


Fig. 1.—Average delayed static deckboard-stringer separation resistance offered by 3″ x 0.120″, hardened-steel pallet nails in 22 hardwoods from southern pine sites.

The average delayed head pull-through resistance of the nails ranged from 704 lb. to 1407 lb., with a grand-average of 1129 lb., and the average delayed shank withdrawal resistance of the nails ranged from 628 to 1522 lb., with a grand-average of 1198 lb. Thus, the grand-average nail-shank withdrawal resistance

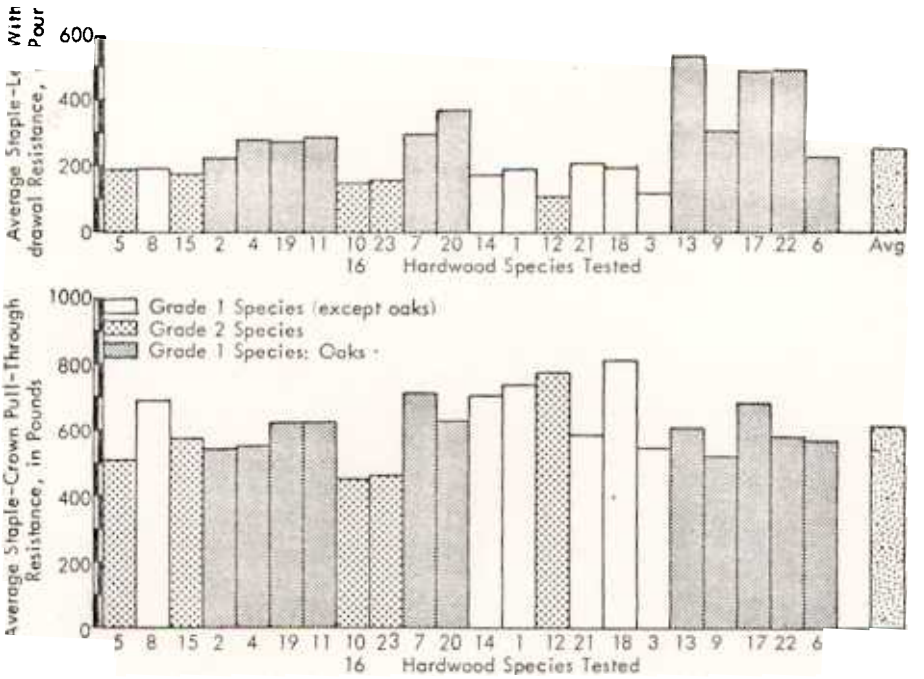


Fig. 2.—Average delayed static deckboard-stringer separation resistance offered by 2½", 15-gauge, 7/16"-crown, Sencote pallet staples in 22 hardwoods from southern pine sites.

in the, on the average, 5% heavier stringers, was 6% higher than the grand-average nail-head pull-through resistance in the deckboards. Consequently, nail-head pull-through resistance and nail-shank withdrawal resistance were balanced.

The average delayed crown pull-through resistance of the staples ranged from 456 to 811 lb., with a grand-average of 614 lb., and the average delayed leg withdrawal resistance of the staples ranged from 105 to 497 lb., with a grand average of 257 lb. Thus, the grand-average staple-leg withdrawal resistance in the, on the average, 5% heavier stringers was 58% lower than the grand-average staple-crown pull-through resistance in the deckboards.

While the nail-head pull-through resistance in only five of the 22 wood species was from 3% to 15% higher than the nail-shank withdrawal resistance, the staple-crown pull-through resistance in each of the 22 species was, on the average, 188% higher than the staple-leg withdrawal resistance, with the difference ranging from 13% to 636% higher.

In the light of the above, with five exceptions, the nail-head pull-through resistance and staple-leg withdrawal resistance were governing the deckboard-stringer separation resistance. On the average, 4.4 staples should have performed as well as a single nail.

The relationships between average (1a) nail-head pull-through resistance, (1b) nail-shank withdrawal resistance, 2a) staple-crown pull-through resistance, and (2b) staple-leg withdrawal resistance, on the one hand, and oven-dry specific gravity, on the other hand, at given moisture contents of deckboards and stringers of the 22

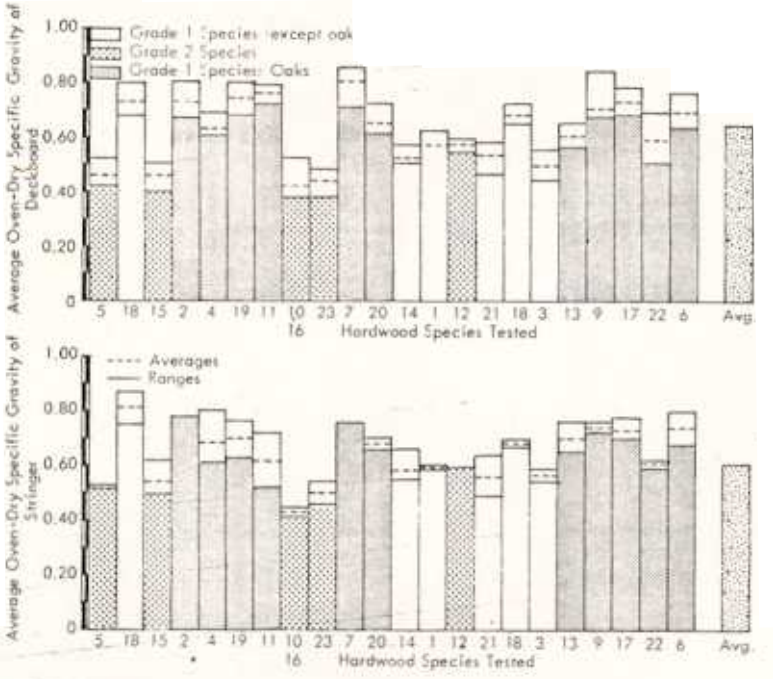


Fig. 3.—Averages and ranges of oven-dry specific gravity of 22 hardwoods from southern pine sites.

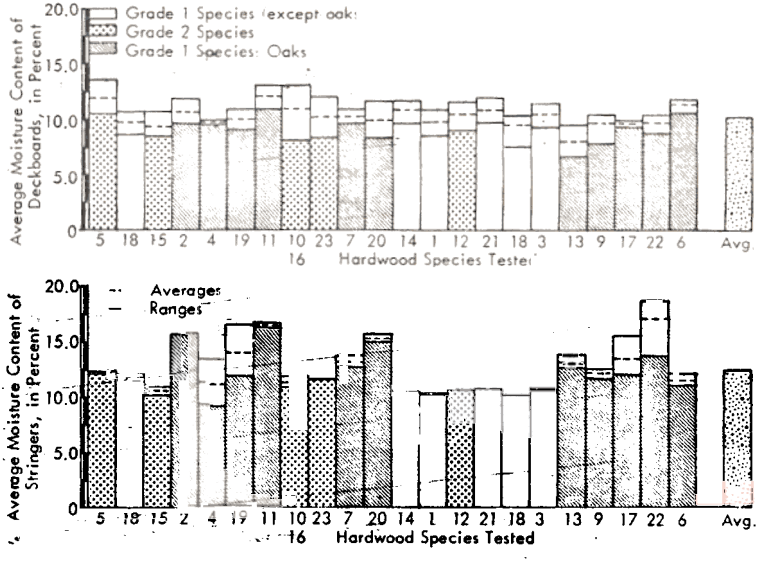


Fig. 4.—Averages and ranges of test moisture content of 22 hardwoods from southern pine sites.

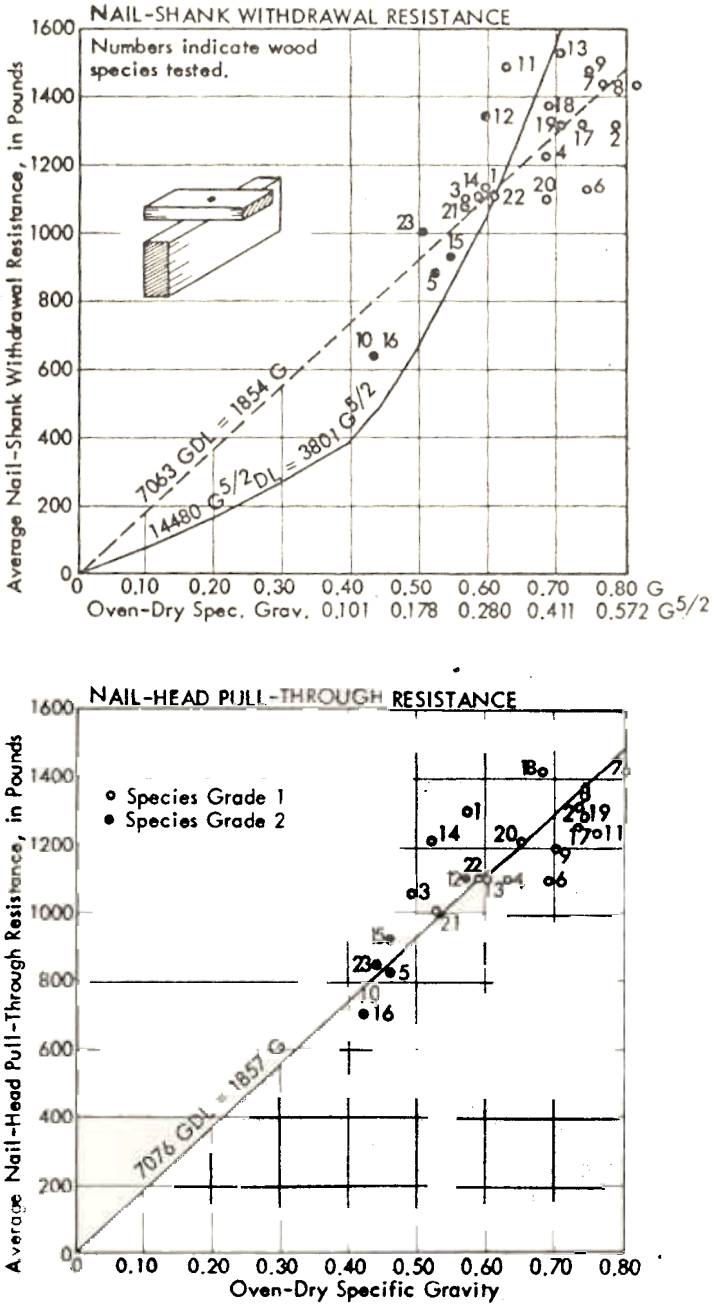


Fig. 5.—Relationship between delayed nail-head pull-through resistance and nail-shank withdrawal resistance and oven-dry specific gravity at given moisture contents of deckboards and stringers of 22 southern hardwoods grown on southern pine sites.

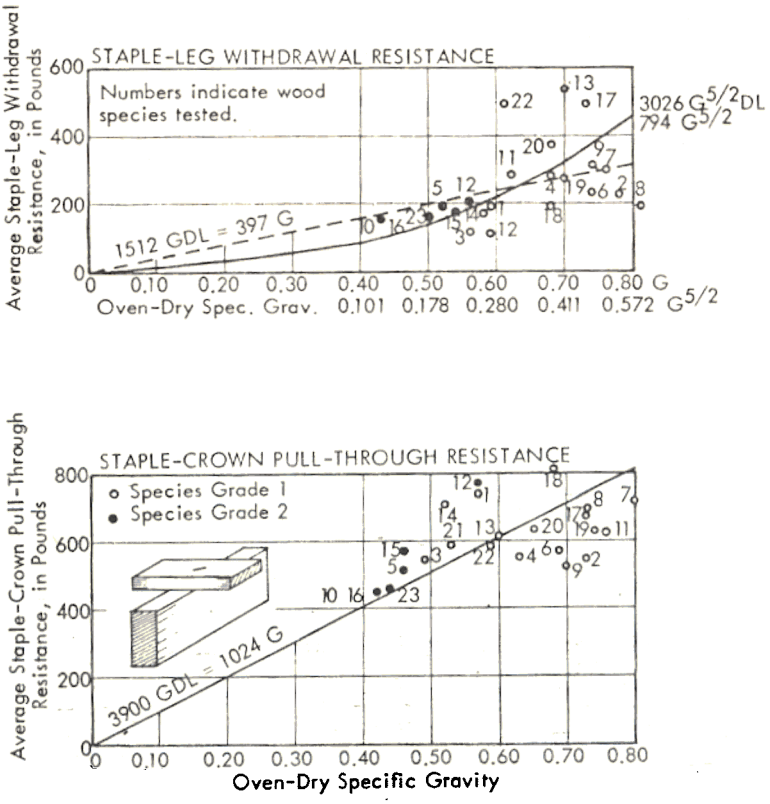


Fig. 6.—Relationship between delayed staple-crown pull-through resistance and staple-leg withdrawal resistance and oven-dry specific gravity at given moisture contents of deckboards and stringers of 22 southern hardwoods grown on southern pine sites.

hardwood species are shown in Figs. 5 and 6. Within the test range, the average delayed

(1a) nail-head pull-through resistance was found to be 7076GDL = 1857G;

(1b) nail-shank withdrawal resistance was found to be $14480G^{5/2}DL$ $3801G^{5/2}$ or 7063GDL = 1854G;

(2a) staple-crown pull-through resistance was found to be 3900GDL = 1024G;

(2b) staple-leg withdrawal resistance was found to be $3026G^{5/2}DL$ $794G^{5/2}$ or 1512GDL = 397G;

where G = Oven-dry specific gravity of the wood members; D = Fastener diameter, in inches; and L = Fastener penetration, in inches; with the resulting values in pounds.

These expressions compare with the empirical formula $P = 6900\ G^{5/2}DL$ for bright *plain-shank* nails driven into the side grain of seasoned wood or unseasoned wood that remains wet according to the 1955 edition of "Wood Handbook", Handbook No. 72 of USDA); where P = Fastener withdrawal resistance per inch of penetration, in pounds.

While the nail-shank and staple-leg withdrawal resistance is normally related to oven-dry specific gravity in accordance with $G^{5/2}$, especially the nail-shank data may be also represented within the test range by a straight-line relationship with the oven-dry specific gravity, G, as is evident from Fig. 5.

The ranges and grand-averages for the delayed test values for the five species of Grade 2 (that is, sweetgum, black tupelo, yellow poplar, sweetbay, and red maple) versus that of the 17 species of Grade 1 (that is, eleven oaks, mockernut hickory, white and green ash, American and winged elm, and hackberry) are given in the following tabulation:

Test Values	Species Grade	Oven-Dry Specific Gravity Deckbd.	Oven-Dry Specific Gravity Stringer	Nail-Head Pull-Through Res. in Lb.	Nail-Shank Withdrawal Res. in Lb.	Staple-Crown Pull-Through Res. in Lb.	Staple-Leg Withdrawal Res. in Lb.
Range		0.49-0.80	0.56-0.81	1053-1407	1082-1522	521-811	120-538
Avg.	1	0.66	0.68	1203	1270	631	286
Range	2	0.42-0.57	0.43-0.59	704-1092	628-1340	456-773	105-188
Avg.	2	0.47	0.52	877	953	556	156
Avg.	2/1	71%	76%	73%	75%	88%	55%

While the average oven-dry specific gravity of the deckboards and stringers of species Grade 2 was 29% and 24% lower, respectively, than that of the deckboards and stringers of species Grade 1, the average delayed test values for nail-head pull-through resistance and nail-shank withdrawal resistance in species Grade 2 were 27% and 25% lower, respectively, than those in species Grade 1; and the average delayed test values for staple-crown pull-through resistance and staple-leg withdrawal resistance in species Grade 2 were 12% and 45% lower, respectively, than those in species Grade 1. These findings are presented graphically in Fig. 7.

The ranges and grand-averages for the delayed test values for the eleven oaks included in this study (that is, post, southern red, water, white, black, cherrybark, northern red, scarlet, shumard, laurel, and blackjack oak) are given in the following tabulation:

Test Values	Species	Oven-Dry Specific Gravity Deckbd.	Oven-Dry Specific Gravity Stringer	Nail-Head Pull-Through Res. in Lb.	Nail-Shank Withdrawal Res. in Lb.	Staple-Crown Pull-Through Res. in Lb.	Staple-Leg Withdrawal Res. in Lb.
Range	11	0.59-0.80	0.61-0.78	1083-1407	1096-1522	521-715	227-538
Avg.	Oaks	0.69	0.70	1199	1308	605	345
Range	22	0.42-0.80	0.43-0.81	704-1407	628-1522	456-811	105-538
Avg.	Species	0.61	0.64	1129	1198	614	257
Avg.	11/22	113%	109%	106%	109%	99%	134%

The eleven oak species are among the 22 hardwood species which provided the highest deckboard-stringer separation resistance, as is shown in the bar diagrams of Fig. 8.

The grand-averages for the delayed test values for the 22 hardwood species are valid for lumber of such average oven-dry specific gravity as was determined during this study. These specific gravity values varied from the aver-

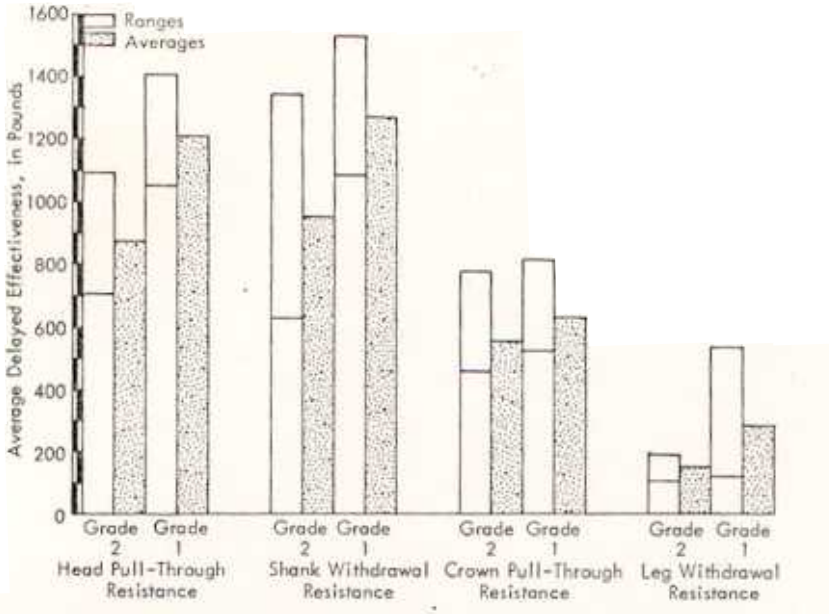


Fig. 7.—Average delayed static deckboard-stringer separation resistance offered by 3" by 0.120", hardened-steel pallet nails and 2½", 15-gauge, 7/16"-crown Sencote pallet staples in five Grade 2 versus 17 Grade 1 hardwoods from southern pine sites.

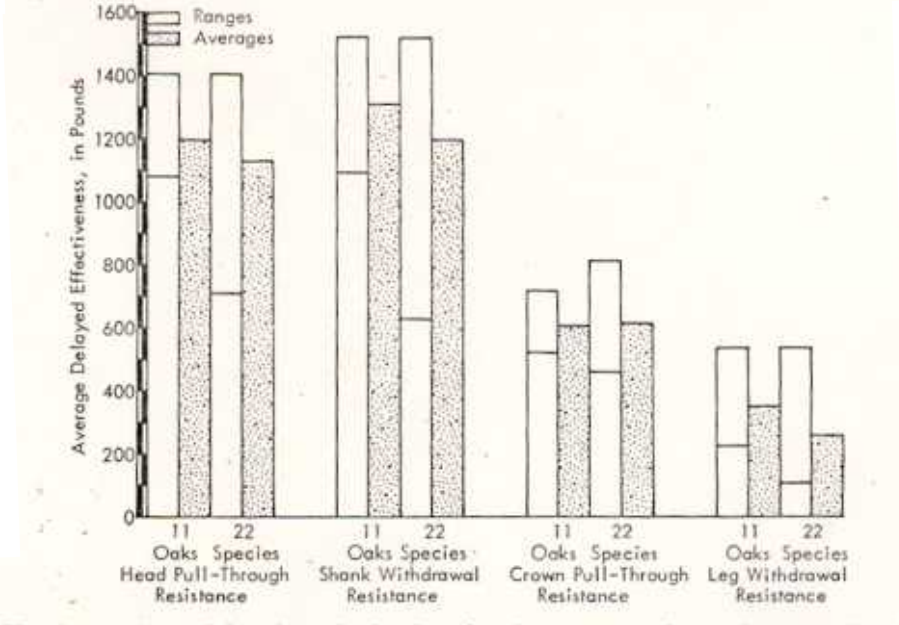


Fig. 8.—Average delayed static deckboard-stringer separation resistance offered by 3" by 0.120", hardened-steel pallet nails and 2½", 15-gauge, 7/16"-crown, Sencote pallet staples in eleven oaks versus 22 hardwoods from southern pine sites.

ages for the 22 hardwood species as previously established (see Table I to III) from −21% to +12% with grand-averages of −7% for the deckboards and −3% for the stringers. In the light of this, the delayed test values were adjusted to be representative for the wood species, as is shown in Table III and Figs. 9 and 10. These adjustments were made in line with the formulae developed during the study. Their validity as well as their limitations are evident from these illustrations.

The reduction of the average delayed test values to the common denominator — that is, the average specific gravity of the wood species as previously established — makes it possible to indicate the average pallet deckboard-stringer separation resistance, in other words, the average performance of the joints made of the 22 hardwood species, based on the lower values of the nail-head or staple-crown pull-through resistance and nail-shank or staple-leg withdrawal resistance. These average joint performance data — derived from the average delayed test values on the basis of the straight-line relationship of the specific gravity, G — are based on eleven nail-head pull-through resistance as well as eleven nail-shank withdrawal resistance values and 22 staple-leg withdrawal resistance values for the 22 hardwood species. They are listed in Table IV and presented graphically in Fig. 11. They may serve as basis for computing the average performance of, including design values for, nailed joints as were tested during this investigation.

It is evident from Fig. 11b that the performance of the nailed joints assembled with lumber of the five Grade 2 species was lower than that of the joints assembled with lumber of Grade 1 species. Furthermore, it can be noted from Fig. 11c that the performance of the stapled joints assembled with lumber of the five Grade 2 species was, with two exceptions (hackberry and mockernut hickory), also lower than that of the joints assembled with lumber of Grade 1 species.

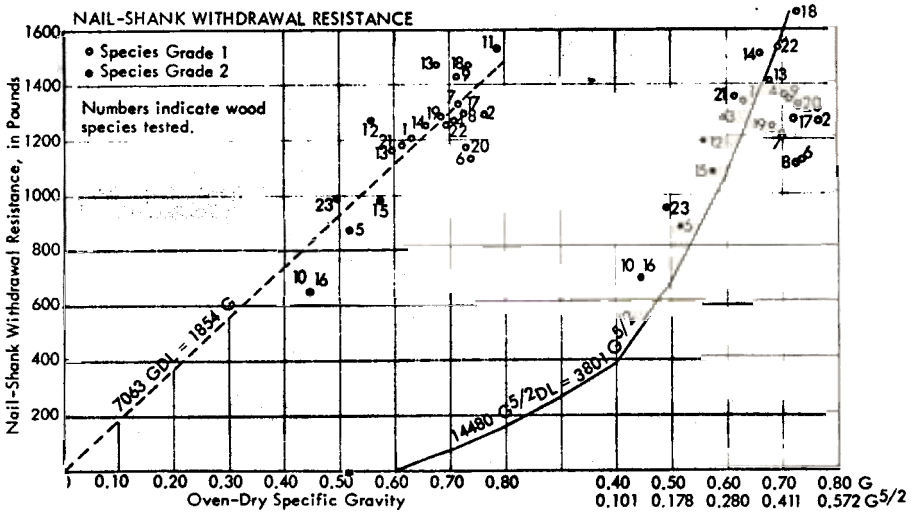
TABLE III

Average Delayed Deckboard-Stringer Separation Resistance of 22 Hardwood Species from Southern Pine Sites
Adjusted for Average Specific Gravity Representative of Wood Species

Species	Species Grade	Test No.	Species Spec. Green Vol. Oven-Dry Weight	Grav. Oven-Dry (a)	Test Oven-Dry Specific Gravity Deckbd.		Stringer		Test Moisture Content Deckbd.	Stringer	Nail-Head Pull-Through Res. in Lb. (b)	Nail-Shank Withdrawal Res. in Lb. (b)	(c)	Staple-Crown Pull-Through Res. in Lb. (b)	Staple-Leg Withdrawal Res. in Lb. (b)	(c)
Sweetgum	2	5	0.448	0.519	0.46	(89%)	0.52	(100%)	11.9	12.2	925	875	873	579	188	187
Mock. Hickory (d)	1	8	0.619	0.729	0.73	(100%)	0.81	(111%)	9.7	11.6	1309	1293	1113	689	171	147
Black Tupelo	2	15	0.502	0.574	0.46	(80%)	0.54	(94%)	9.3	10.6	1150	981	1073	718	186	203
Post Oak	1	2	0.660	0.767	0.73	(95%)	0.78	(102%)	10.7	15.6	1325	1295	1263	571	222	217
South. Red Oak	1	4	0.609	0.707	0.63	(89%)	0.68	(96%)	9.5	11.2	1215	1271	1354	621	291	310
Water Oak	1	19	0.587	0.682	0.74	(108%)	0.70	(103%)	10.0	14.0	1174	1282	1236	576	264	254
White Oak	1	11	0.673	0.783	0.76	(97%)	0.62	(79%)	12.1	16.3	1272	1527	2670	643	361	515
Yellow Poplar	2	10 16	0.397	0.447	0.42	(94%)	0.43	(96%)	11.0	11.2	749	652	690	485	158	167
Sweetbay	2	23	0.437	0.493	0.44	(89%)	0.50	(101%)	10.3	10.6	947	984	959	519	158	154
Black Oak	1	7	0.620	0.714	0.80	(112%)	0.76	(106%)	10.3	13.2	1256	1334	1210	639	278	252
Cherrybark Oak	1	20	0.633	(0.730)	0.65	(89%)	0.68	(93%)	9.9	15.3	1356	1177	1320	704	401	451
White Ash	1	14	0.582	0.659	0.52	(79%)	0.58	(88%)	10.8	(10.5)	1540	1249	1511	897	197	238
Green Ash	1	1	0.561	0.631	0.57	(90%)	0.59	(94%)	9.7	10.2	1437	1202	1326	818	204	225
Red Maple	2	12	0.496	0.558	0.57	(102%)	0.59	(106%)	10.2	10.5	1069	1267	1179	757	99	92
American Elm	1	21	0.536	0.614	0.53	(86%)	0.56	(91%)	10.8	10.6	1142	1186	1358	678	224	256
Winged Elm	1	18	0.623	0.733	0.68	(93%)	0.68	(93%)	9.5	10.0	1517	1476	1664	874	206	232
Hackberry	1	3	0.525	0.597	0.49	(82%)	0.56	(94%)	10.4	10.6	1283	1159	1267	664	128	140
North. Red Oak	1	13	0.597	0.679	0.60	(88%)	0.70	(103%)	8.0	13.2	1228	1476	1411	689	522	499
Scarlet Oak	1	9	0.622	0.713	0.70	(98%)	0.74	(104%)	9.4	12.1	1220	1423	1340	531	300	282
Shumard Oak	1	17	0.625	(0.722)	0.73	(101%)	0.73	(101%)	9.6	13.5	1234	1297	1277	676	489	481
Laurel Oak	1	22	0.583	0.694	0.59	(85%)	0.61	(88%)	9.7	17.0	1283	1255	1529	685	565	689
Blackjack Oak	1	6	0.638	(0.739)	0.69	(93%)	0.74	(100%)	11.4	11.5	1176	1121	1121	610	227	227
Average		22	0.572	0.658	0.61	(93%)	0.64	(97%)	10.2	12.3						

(a) Adjusted in accordance with Table 3-5 of Wood Handbook: Wood as an Engineering Material, U.S.D.A. Forest Service, Agriculture Handbook No. 72, page 3-9, August, 1974.

(b) Adjusted in accordance with G. (c) Adjusted in accordance with $G^{5/2}$. (d) Serving as representative of the true hickories.



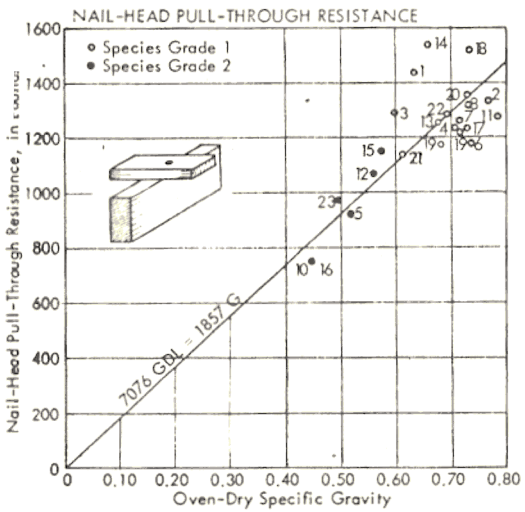


Fig. 9.—Relationship between delayed nail-head pull-through resistance and nail-shank withdrawal resistance and oven-dry specific gravity at given moisture contents of deckboards and stringers of 22 southern hardwood species.

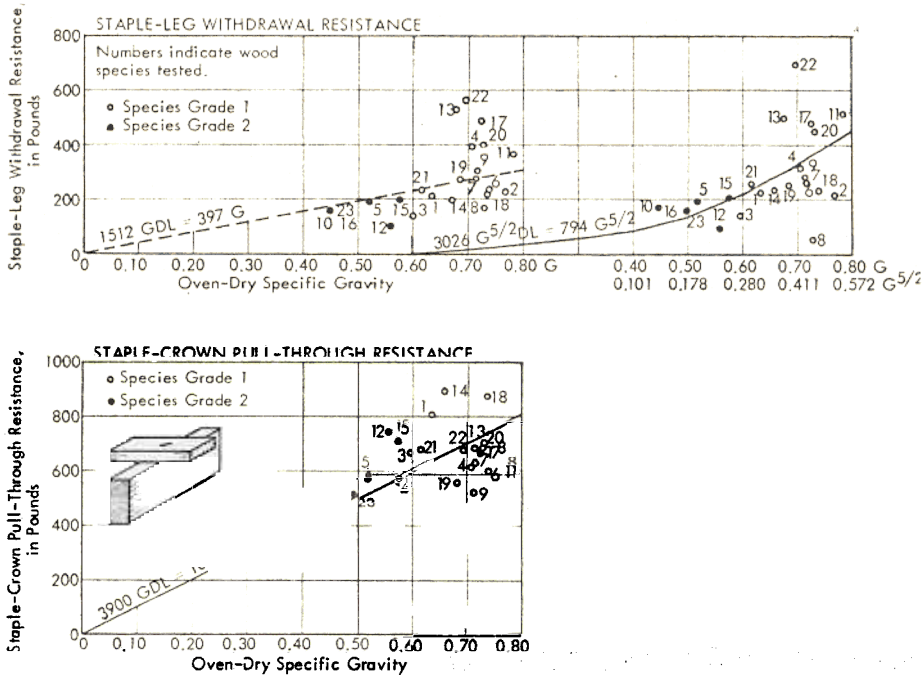


Fig. 10.—Relationship between delayed staple-crown pull-through resistance and staple-leg withdrawal resistance and oven-dry specific gravity at given moisture contents of deckboards and stringers of 22 southern hardwood species.

TABLE IV

Average Delayed Joint Performance of 22 Hardwood Species from Southern Pine Sites Based on Average Specific Gravity Representative for Wood Species and Lower Values for Nail-Head or Staple-Crown Pull-Through Resistance and Nail-Shank or Staple-Leg Withdrawal Resistance, in Pounds

Species	Species Grade	Test No.	Species Spec. Grav. Green Vol, Oven-Dry Weight	Oven-Dry	Nailed Joint	Stapled Joint
Sweetgum	2	5	0.448	0.519	875	188
Mock. Hickory*	1	8	0.619	0.729	1293	171
Black Tupelo	2	15	0.502	0.574	981	186
Post Oak	1	2	0.660	0.767	1295	222
South. Red Oak	1	4	0.609	0.707	1215	291
Water Oak	1	19	0.587	0.682	1174	264
White Oak	1	11	0.673	0.783	1272	361
Yellow Poplar	2	10 16	0.397	0.447	652	158
Sweetbay	2	23	0.437	0.493	947	158
Black Oak	1	7	0.620	0.714	1256	278
Cherrybark Oak	1	20	0.633	(0.730)	1177	401
White Ash	1	14	0.582	0.659	1249	197
Green Ash	1	1	0.561	0.631	1202	204
Red Maple	2	12	0.496	0.558	1096	99
American Elm	1	21	0.536	0.614	1142	224
Winged Elm	1	18	0.623	0.733	1476	206
Hackberry	1	3	0.525	0.597	1159	128
North. Red Oak	1	13	0.597	0.679	1228	522
Scarlet Oak	1	9	0.622	0.713	1220	300
Shumard Oak	1	17	0.625	(0.722)	1234	489
Laurel Oak	1	22	0.583	0.694	1255	565
Blackjack Oak	1	6	0.638	(0.739)	1121	227

*Serving as representative of the true hickories.

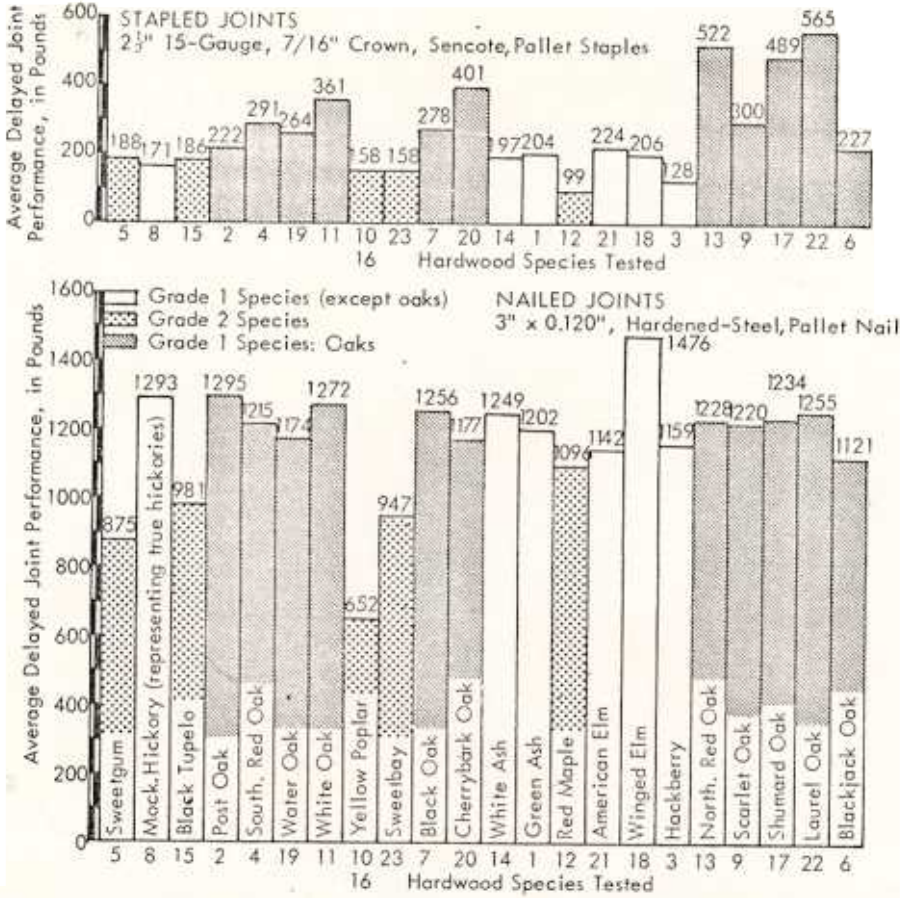


Fig. 11a.—Average delayed joint performance of 22 hardwood species from southern pine sites based on average species specific gravity and lower values for nail-head and staple-crown pull-through resistance and nail-shank and staple-leg withdrawal resistance (arranged in sequence of predominance).

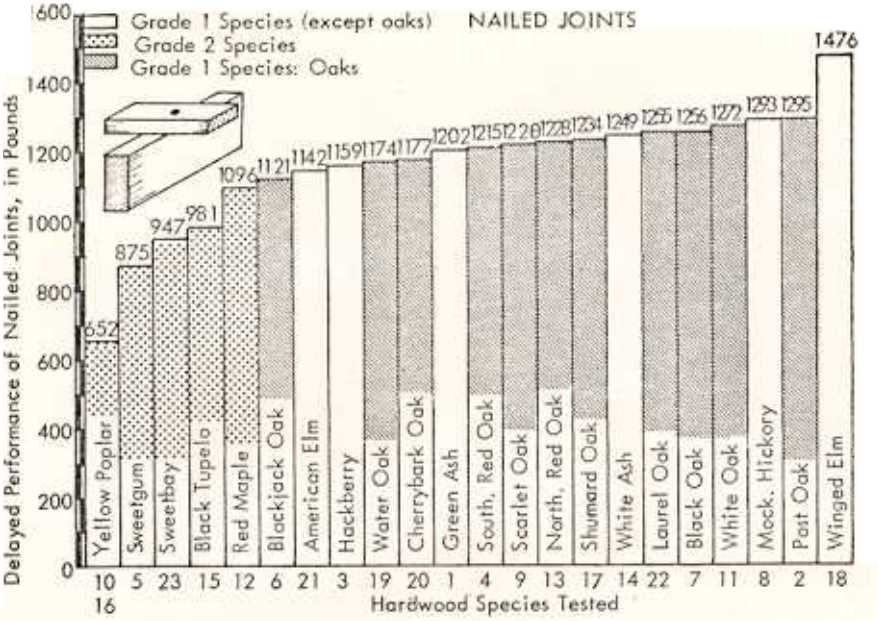


Fig. 11b.—Average delayed joint performance of 22 hardwood species from southern pine sites based on average species specific gravity and lower values for nail-head pull-through resistance and nail-shank withdrawal resistance (arranged in sequence of pallet-nail performance in given wood species).

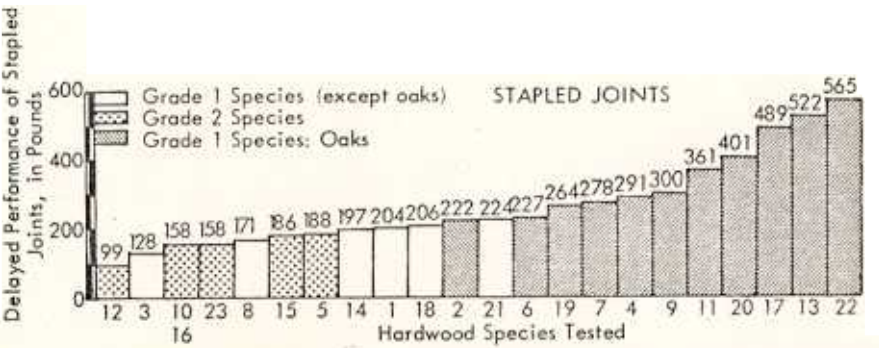


Fig. 11c.—Average delayed joint performance of 22 hardwood species from southern pine sites based on average species specific gravity and lower values of staple-crown pull-through resistance and staple-leg withdrawal resistance (arranged in sequence of pallet-staple performance in given wood species).

SUMMARY

Both nailed and stapled pallet deckboard-stringer joints were assembled with 22 hardwoods grown on southern pine sites. These hardwoods included green and white ash, American and winged elm, hackberry, mockernut hickory, red maple, eleven oaks (black, blackjack, cherrybark, laurel, northern red, post, scarlet, shumard, southern red, water, and white oak), sweetbay (magnolia), sweetgum, black tupelo, and yellow poplar. The specific gravity of the tested lumber varied from the averages for the 22 hardwood species, as previously determined, from −21% to +12%, with grand-averages of −7% for the deckboards and −3% for the stringers.

The joints consisted of 13/16 by 1½ by 6-inch deckboards crossing nominal 2 x 4 stringers of the same species. Each joint was assembled with a single fastener when the lumber was green; and tested for static deckboard-stringer separation resistance in the fastener direction when the lumber was seasoned to an average moisture content of 10% of the deckboards and 12% of the stringers. The fasteners were (a) hammer driven, pointless, helically threaded, hardened-steel, 3 by 0.120-inch, pallet nails with umbrella head and (b) gun-driven, 2½-inch, 15-gauge, 7/16-inch crown, galvanized, plastic-coated, pallet staples.

Within the test range under scrutiny, the overall delayed nail-head pull-through resistance was $7076GDL = 1857G$; the nail-shank withdrawal resistance was $14480\ G^{5/2}DL = 3801G^{5/2}$ or $7063GDL = 1854G$; the staple-crown pull-through resistance was $3900GDL = 1024G$; and the staple-leg withdrawal resistance was $3026G^{5/2}DL = 794G^{5/2}$ or $1512GDL = 397G$; with the resulting values in pounds.

Specific average performance values were derived for the described joints made of, and representative for, the 22 hardwood species investigated, to serve as a basis for arriving at design values under given use conditions. When determining such design values, consideration need to be given to the fact that the tested joints were of such dimensions that end splitting by the tested fasteners was eliminated, while such end splitting may occur in the field where the distance between nail and deckboard end is often less than required to eliminate end splitting. In contrast, end splitting by the tested staples has been observed rarely in the field because of the slenderness of the legs of the tested pallet staples.

APPENDIX

Detailed Test Data

APPENDIX TABLE 1

Delayed Deckboard-Stringer Separation Resistance of 22 Species of Hardwoods from 5 Southern Pine Sites

Species Name	Sweetgum		Mock. Hickory		Black Tupelo		Post Oak		Southern Red Oak		Water Oak	
Species Number	5		8		15		2		4		19	
Deckbd. Sp. Gr.	0.42-0.50		0.68-0.80		0.40-0.50		0.67-0.80		0.60-0.69		0.68-0.80	
Avg. Dbd. Sp. Gr.	0.46		0.73		0.46		0.73		0.63		0.74	
Str. Sp. Gr.	0.52-0.53		0.75-0.87		0.50-0.62		0.78		0.61-0.80		0.63-0.76	
Av. Str. Sp. Gr.	0.52		0.81		0.54		0.78		0.68		0.70	
Deckbd. M.C.	10.5-13.5		8.6-10.7		8.4-10.7		9.6-11.9		9.4-9.8		9.1-10.9	
Avg. Dbd. M.C.	11.9		9.7		9.3		10.7		9.5		10.0	
Str. M.C.	12.0-12.3		11.4-11.9		10.2-10.9		15.6-15.7		9.2-13.0		11.8-16.5	
Av. Str. M.C.	12.2		11.6		10.6		15.6		11.2		14.0	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Deckboard Stringer Separation Resistance, in Lb., by Nail No. 1785: 1	695	845	1533c	1370	862	892	1500c	1450	1095c	1200	1410c	1235
2	---	770	1410c	1325	945	852	1367c	1455	1040c	1280	1510c	995
3	060c	840	1358	1587	1000	973	1253c	1595	1200c	1285	1325c	1080
4	050c	755	817c	1762	1005	930	1350c	1200	1040	1115	1375c	1100
5	762	855	767c	1310	975	944	1315c	1180	1140c	1245	1200c	1445
6	738	935	1005c	1345	862	825	1330	1760	1140c	1355	1250c	1420
7	830	860	1628c	1405	915	1015	1128	1345	950c	1315	1140	1215
8	975	1020	1550c	1492	885	1188	905	1000	1165c	1085	1380c	1412
9	700	892	1440c	1645	890	810	1155	1040	1140	1175	1400c	1440
10	742	860	1403c	1165	828	895	1395c	1340	1088c	1080	1255c	1500
11	742	925	1400c	1537	881	845	1030	1320	870c	1475	1380c	1370
*12	725	963	1418c	1303	1015c	910	1405c	1115	1130	1060	660c	1585
Avg	820	877	1311	1437	922	923	1261	1317	1083	1222	1274	1316
Deckboard Stringer Separation Resistance, in Lb., by Staple Nos. 1732, 1370, 1369: 1	490	132	722c[1]	175	505	196	530	125	750	419	720	425
2	478	127	622	208	740	176	685	293	510	381	740	286
3	583	211	780c	164	558	148	545	220	475	261	608	250
4	493	170	705c[2]	135	453	124	830	305	610	302	738	196
5	494	164	617c[1]	203	515	213	530	288	450	310	330c[1]	251
6	444	168	675c[2]	197	725	243	625	262	275	416	698	220
7	542	236	568c[2]	196	530	148	505	174	575	245	325c	240
8	576	208	710c[1]	204	562	158	655	200	675	265	915c[2]	225
9	522	189	815c[1]	178	570	177	425	130	675	159	598c[2]	330
10	465	191	605c[1]	215	728	167	545	215	425	178	575c[2]	323
11	568	246	685c[1]	213	557	178	240c[1]	198	635c[1]	289	790c[2]	262
12	499	220	775c[1]	189	460	174	600	308	585	130	465c[1]	248
Avg	513	188	609	190	575	175	543	226	553	280	625	271
Staple/Nail, in Pct.	63	21	53	32	62	19	43	17	51	23	49	21

Species Name	White Oak		Yellow Poplar		Yellow Poplar		Sweetbay		Black Oak		Cherryb. Oak	
Species Number	11		10		16		23		7		20	
Deckbd. Sp. Gr.	0.72-0.79		0.38-0.50		0.39-0.52		0.38-0.48		0.71-0.85		0.61-0.72	
Avg. Dbd. Sp. Gr.	0.76		0.41		0.42		0.44		0.80		0.65	
Str. Sp. Gr.	0.52-0.72		0.41-0.42		0.44-0.45		0.46-0.54		0.76		0.66-0.70	
Av. Str. Sp. Gr.	0.62		0.42		0.44		0.50		0.76		0.68	
Deckbd. M.C.	10.9-13.1		9.1-13.1		8.1-12.7		8.4-11.9		9.7-10.9		8.3-11.6	
Avg. Dbd. M.C.	12.1		10.9		11.2		10.3-		10.3		9.9	
Str. M.C.	16.3-16.7		11.2-11.7		10.8-11.1		10.6		12.8-13.2		14.9-15.6	
Av. Str. M.C.	16.3		11.4		11.0		10.6		13.2		15.3	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Nail No. 1785: 1	1440	1255	708	505	695	620	983c	1110	1575c	1500	1160	1115
2	1510c	1470	742	512	640	803	825c	1105	1415c	1315	1100	847
3	1135c	1385	709	528	660	662	915	765	1545c	1600	897c	1275
4	1050c	1685	710	410	625	762	950	860	1465c	1320	1390c	997
5	1135	1390	752	395	790	827	940	897	1440c	1310	955c	1135
6	1110	1715	722	472	740	642	1005	940	1330	1365	1240c	1175
7	1087c	1710	613	585	822	675	777	1045	1600c	1500	1197c	1360
8	1175	1075	667	497	650	780	793	1100	865c	1620	1270c	1075
9	1335	1540	775	583	773	665	633c	1025	1560c	1334	1315c	1085
10	1260	1360	653	576	735	718	838	925	1152c	1500	1290c	1015
11	1360	1480	650	593	725	845	757	1110	1470c	1470	1435c	1040
*12	1235	1725	748	551	595c	885	725	1100	1470c	1205	1230c	1040
Avg	1235	1482	704	517	740	740	845	998	1407	1420	1207	1096
Staple: 1	750c[1]	300	503	117	415	240	675	139	815c[2]	301	690	353
2	700	318	385	69.0	430	260	478	158	870c[2]	796	685	280
3	660	335	525	98.0	445	225	260c[1]	183	815c[2]	156	500c[1]	199
4	550c[1]	280	545	116	493	200	485	209	830	194	540c[1]	277
5	635	200	447	125	454	190	575	150	850c[2]	152	525	450
6	410	260	512	145	497	210	275	134	555	143	625	371
7	685c[1]	265	438	108	493	140	325c[1]	161	635	318	515c[1]	268
8	635c[1]	275	590	109	347	140	535	158	500	174	805	251
9	660c[1]	300	468	108	357	195	525	170	792	310	690	556
10	660	310	509	121	360	150	585	163	325c[1]	310	610	575
11	420c[1]	315	517	102	399	210	420	181	820	360	580	554
12	725	270	393	104	430	175	425	120	775c[2]	336	755	354
Avg	624	286	486	110	427	195	463	160	715	296	627	374
Staple/Nail, in Pct.	51	19	69	21	81	26	55	16	51	21	52	34

Species Name	White Ash		Green Ash		Red Maple		Amer. Elm		Winged Elm		Hackberry	
Species Number	14		1		12		21		18		3	
Deckbd. Sp. Gr.	0.50-0.57		0.54-0.62		0.54-0.59		0.46-0.58		0.65-0.72		0.44-0.55	
Avg. Dbd. Sp. Gr.	0.52		0.57		0.57		0.53		0.68		0.49	
Str. Sp. Gr.	0.55-0.66		0.58-0.60		0.59		0.49-0.64		0.67-0.70		0.54-0.59	
Av. Str. Sp. Gr.	0.58		0.59		0.59		0.56		0.68		0.56	
Deckbd. M.C.	9.6-11.6		8.5-10.8		8.9-11.5		9.6-11.9		7.5-10.5		9.3-11.4	
Avg. Dbd. M.C.	10.8		9.7		10.2		10.8		9.5		10.4	
Str. M.C.	(10.5)		10.0-10.3		10.5		10.6-10.7		9.9-10.0		10.5-10.7	
Av. Str. M.C.	(10.5)		10.2		10.5		10.6		10.0		10.6	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Nail No. 1785: 1	1162c	1115	1290c	965	1375c	1200	888	810	1018c	1255	1100c	1010
2	1390c	980	1333c	1195	650c	1305	985	840	1353c	1307	1037	1062
3	733c	1250	1250c	1210	1400c	1275	1045	960	1562	1345	1060	1077
4	1045	1150	1445c	985	625c	1425	995	917	1427c	1325	1122c	1360
5	1190c	938	1130c	1317	1410c	1495	1037	920	1450c	1325	1030	1095
6	1290c	1195	1278c	925			770	710	1275c	1325	900c	944
7	1383c	1258	1248c	1355			995c	1330	1330c	1555	1035	1005
8	1335c	1175	1265c	1040			1003	1325	1490c	1450	958c	997
9	952c	915	1275c	1368			1060	1125	1412c	1325	995	1225
10	1225c	925	1362c	1185			1050c	1425	1525c	1275	1125	1003
11	1625c	1103	1343	1090			1100c	1490	1567c	1475	1100c	1170
*12	1250c	1185	1355c	855			900	1130	1475c	1462	1177c	1045
Avg	1215	1099	1298	1124	1092	1340	986	1082	1407	1369	1053	1087
Staple: 1	825	145	507	172	862c[2]	102	750	183	705c[2]	111	470	130
2	790	145	650	183	855	126	675	194	765c[2]	175	740	975
3	720	216	708	185	537c[1]	112	480	200	806c[2]	153	497	860
4	670	83	827	163	750	89.0	525	197	740c[1]	160	612	162
5	840c[1]	168	800	146	862c[2]	80.0	550	181	865	152	658	950
6	840	203	845	120			530	185	762	148	497	130
7	765	218	730	205			325c[1]	248	760c[2]	162	508	137
8	690	235	815	217			500	185	900	165	458	129
9	740	152	645	170			590	202	885c[2]	166	502	126
10	815	156	803	235			765	206	805c	295	553	119
11	465	163	635	228			725	256	880c[2]	303	487	114
12	335	193	900c[2]	166			610	206	862c[2]	298	555	118
Avg	708	173	739	191	773	105	585	204	811	191	545	120
Staple/Nail, in Pct.	58	16	57	17	71	8	59	19	58	14	52	11

Species Name	Northern Red Oak		Scarlet Oak		Shumard Oak		Laurel Oak		Blackj. Oak	
Species Number	13		9		17		22		6	
Deckbd. Sp. Gr.	0.56-0.65		0.67-0.84		0.68-0.78		0.50-0.69		0.63-0.76	
Avg. Dbd. Sp. Gr.	0.60		0.70		0.73		0.59		0.69	
Str. Sp. Gr.	0.65-0.76		0.72-0.76		0.70-0.77		0.59-0.62		0.68-0.80	
Av. Str. Sp. Gr.	0.70		0.74		0.73		0.61		0.74	
Deckbd. M.C.	6.7-9.4		7.9-10.3		9.3-9.8		8.7-10.4		10.5-11.7	
Avg. Dbd. M.C.	8.0		9.4		9.6		9.7		11.4	
Str. M.C.	12.6-13.8		11.8-12.4		11.9-15.5		13.7-18.7		11.0-12.0	
Av. Str. M.C.	13.2		12.1		13.5		17.0		11.5	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Nail No. 1785: 1	1225c	1490	1235c	1570	1250c	1435	800c	1090	985	1203
2	475c	1695	805c	1550	715c	1562	1350c	1140	1100c	1222
3	1275c	1438	920c	1515	1253	1110	1425c	1040	1162	1143
4	1088	1710	1415c	1490	1465c	1315	1268	1053	1147	925
5	855c	1600	1500c	1568	1460c	1525	1185c	1142		
6	1165c	1355	1235c	1490*	1200c	1450	1035c	1088		
7	1180c	1615	1195	1225	1252	1510	940	995		
8	1125c	1550	1230	1365	1225c	1265	1245	1035		
9	1240c	1445	1225c	1500	1280	1252	958	1235		
10	1200c	1455	1250	1530	1290c	1115	1022c	1077		
11	1115	1370	1140	1480	1295c	985	895c	1245		
*12	1080c	1537	1225	1440	1285c	1208	943	1097		
Avg	1085	1522	1198	1477	1248	1311	1091	1103	1098	1123
Staple: 1	850	464	720	282	760	650	513	590	587	265
2	670	515	570	328	820	550	511c[1]	511c[1]	595	240
3	618	490	630	378	895c[2]	438	793c[1]	308	515	245
4	662	471	305c[1]	294	700	515	476c[2]	495c[2]	583c[2]	157
5	685	538	580	342	790c[2]	415	677	695		
6	595	472	605	401	700	495	595	525		
7	658	610	275c[1]	140	708	545	543	545		
8	572	588	575	192	550	605	733	450		
9	496	630	450c[1]	356	640	435	545	445		
10	502	605	575c[1]	372	475	412	606	430		
11	545	562	570	341	608	446	425	416		
12	453	515	400c[1]	406	610	428	568	555		
Avg	609	538	521	311	683	494	582	497	570	227
Staple/Nail, in Pct.	56	35	43	21	55	38	53	45	52	20

(a) Nail-head or staple crown pull-through resistance.
(b) Nail-shank or staple-leg withdrawal resistance.
(c) Fastener fai

Deckboard: 13/16" x 1½" x 6".
Stringer: 2 x 4.
Fastener spacing in stringer: 3" o.c. and 2" (minimum) from end.