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FOREST PRODUCTS LABORATORY
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THE SIGNIFICANCE OF THE DISCOLORATIONS IN YELLOW-POPLAR VENEERS

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METHODS

The wood of yellow-poplar (Liriodendron tulipifera), in the living tree, is very variable in color. These colorations almost cover the range of the rainbow. What they mean with respect to the strength of the wood has been the subject of much conjecture. In view of the use of this species in aircraft and other construction, where it is important to obtain maximum strength with minimum weight, it seemed urgent to know something of the significance of these colorations. Preliminary tests indicated that the toughness of rotary veneer cut from yellow-poplar, as measured in the intermediate-capacity Forest Products Laboratory toughness machine, would give a reasonable all-around measure of strength for most purposes, and such tests were simple to make. Accordingly, test pieces were cut from mill-run veneer from two Appalachian mills, and colored sticks were compared in toughness with bright sticks from the same sheet.

The veneer test sheets varied in thickness from 1/24 inch to 3/16 inch. The test pieces from these sheets were cut 1/2 by 5 inches, with the long axis being parallel to the grain. In all cases the colored pieces were cut from near the border of the colored and bright wood, so that each colored piece could be compared with a bright stick not more than 1 inch away, and usually closer, as in figure 1.

In preparing the test sticks, the sheets from which they were to be cut were conditioned in a room at 65 percent relative humidity and at a temperature of 80° F. for 48 hours. The sticks were then sawed out, to exact width and length, outside the humidity room in as short a time as possible (usually 2 to 4 hours). After being cut, the sticks were further conditioned in a room at 65 percent relative humidity, and at 75° F. In this room the average thickness of each piece was measured to 1/1000 inch, and the sticks were weighed. They were then tested[3]

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[3] Span was 2-1/2 inches, and load was applied at the center.

for toughness in the intermediate-capacity toughness machine, and the broken sticks were then dried for 48 hours at 100° C. and reweighed for specific gravity determinations.

The relative toughness of bright and colored wood was expressed as the ratio of the toughness of each colored stick to its adjacent bright stick (e.g., $\frac{b}{a}, \frac{d}{c}, \frac{f}{e}$). These ratios, for a given color or type of coloration, were then averaged (using the geometric mean), and standard errors were computed.[4]

Henceforth in this discussion, when the "toughness ratio" is referred to, the ratio of the toughness of a colored stick to its adjacent bright stick will be meant. A ratio of 1 means that the two were of the same toughness, of greater than 1 means that the colored was stronger, and of less than 1, that the colored was weaker. Specific gravity ratios were computed in a similar manner.

RESULTS

In table 1 the relative toughness of colored sticks is presented, separated both on the basis of color alone, and also on the basis of the type of coloration. Also given in the table are data on the relative specific gravities, to aid in interpretation of the toughness data.

The veneer was collected largely from two mills about 200 miles apart, in the southern Appalachians. The data from the two mills showed fair agreement on the major points.

The only color significantly weaker than the bright was brown. The browns, other than normal tan heartwood, were divided into rot and discolorations that appeared not to be rot (but in some cases might have been rot). While only the rot was statistically significantly weak, brown, not rot, also appeared to be weak. Among the types of coloration only insect streaks and rot were significantly weaker than bright wood. The rotted veneer tested was almost all in the early or incipient stage, in which untrained men might not recognize it as rot. All rots were brown in color. Reductions in toughness of less than 10 percent from the average can probably be disregarded for most purposes, since variations in toughness of 15 to 20 percent are common among sticks cut from different parts of a normal sheet, depending largely on specific gravity.

[4] Differences are called "significant" if they are so much larger than the normal variation that it is unlikely that they were due to chance.

Toughness was generally related to specific gravity. Several colorations had specific gravity ratios significantly greater than 1, and only rot had ratios significantly less than 1. This indicates that whatever causes these colorations tends to raise the specific gravity. Microscopic examination of most of the colorations shows considerable dark deposit in the ray cells, and these deposits would be expected to raise the specific gravity, probably without materially affecting the toughness. In the case of 123 bright sticks of uniform thickness (0.040 - 0.046 inch) toughness was related to specific gravity as shown in figure 2.

DESCRIPTION OF COLORATIONS AND SUGGESTIONS ON CULLING WHEN MAXIMUM STRENGTH IS IMPORTANT

Normal Heartwood

The color of normal heartwood varies from bright light green to a pale tan, and it is always distinguishable from discolorations by the light green or pale tan color, uniformity of color, and lack of water soak.

In general, normal heartwood is no weaker than sapwood, although there was an average drop of 8 percent in toughness (that was not statistically significant) at one of the mills. Specific gravity is about the same as in sapwood. Surface smoothness and warping are practically the same as in sapwood. Do not reject.

Blue-Butt

Blue-butt is perhaps the most prevalent coloration of yellow-poplar. It extends upward from the base of large trees and usually runs out within 16 feet of the stump cut. It may involve all of the wood radially to within a few inches of the bark, and there is a sharp line of demarcation between colored and bright wood. Generally, where the colored and bright wood meet, there is a narrow band of purplish or greenish brown. Inside this zone the wood may be colored reddish, purple, or lavender, with some areas dark green. Fresh logs that are blue on the ends are often green inside. The wood is frequently water-soaked and may be very heavy for this reason. The color of this wood is due to a uniform coloration of the cell walls, together with dark deposits in the ray cells.

Blue-butt is not significantly lower in toughness than bright wood. Warping and surface smoothness are the same as in normal wood. None of the colorations that make up blue-butt, including red, purple, lavender, purplish brown and green, would seem to warrant rejection.

General Discolorations

General discolorations are widespread discolorations that are set apart from blue-butt partly because most of them are green, and also because they often do not follow the blue-butt pattern of extending up from the base. They may develop from trunk wounds or other local disturbances. In addition to dark green, many such discolorations are shades of lavender and purple and a few are brown. The greens are much darker than normal heart and are frequently water-soaked and heavy. The colors are due largely to a change in color of all of the cell walls and to dark contents in the ray cells.

Wood with these general discolorations is as tough as normal wood, with a slightly but consistently higher specific gravity, apparently due to deposits in ray cells. Warping and surface smoothness are practically the same as in normal wood. No reason was encountered for discriminating against general discolorations, other than brown.

Sap Stain

Sap stain is called "cutting stain" at some mills, and it is also called blue stain. It is actually pink when fresh and gray when dry, in yellow-poplar. It extends in from the ends of the logs a foot or more. It develops rapidly in warm weather. The gray color is usually imparted by the fungus _Endoconidiophora coerulescens_, which permeates the rays of the wood. Sap stain is not a stage of decay, although it is fungus-caused. Some sap-stain fungi other than _E. coerulescens_ can cause similar stain in yellow-poplar logs, but 80 percent of the successful isolations thus far made from the sap stain from two localities yielded _E. coerulescens_.

Although the sap-stained veneer was not shown in these particular tests on yellow-poplar to be reduced in toughness, in tests on other woods blue stain has been found to affect the strength. Sap-stained material should be inspected carefully to insure against the presence of decay and should be dried at sufficiently high temperatures to kill the stain fungi.

Insect Streaks

A timber worm whose action is similar to that of flagworms in oak, commonly bores into the sapwood of living yellow-poplar and produces a few short brood tunnels. Streaks, purple, green, or black in color, and often a foot or more in length either way from the holes, always develop from these worm holes.

The insect streaks are significantly less tough than bright wood. The average reduction in toughness was only 7 percent. A sheet with such a streak will usually tear where the streak and bright wood meet, indicating weakness perpendicular to the grain, but all thin veneer is weak in this direction. Warping of the streaked part is different from the bright wood, so that there is often a hump, perpendicular to the grain, where the sheet is streaked. The insect holes themselves, always few in number, constitute only a minor local defect. Since insect streaks are very narrow and not materially less tough than bright wood, it is not considered necessary to cull them, but they might well be trimmed out where this does not interfere with the use of the rest of the sheet.

Fire Streaks

Fire streaks are short black streaks, seldom more than a few inches long. They somewhat resemble insect streaks but are usually much shorter, do not have insect holes at the center, and are always black. This name might be a misnomer, but one experienced veneer man insisted that they were caused by forest fires burning through the bark or burning small stubs. Even should they in fact not be caused by fire, the name might not be inappropriate because of their black, charred appearance.

The few streaks that were tested did not show up weak in toughness. Nevertheless, they exhibit the same weakness perpendicular to the grain as insect streaks, and similar warping characteristics. Their very high specific gravity indicates difference in density. There is frequently a break in the wood or a black knot in the center of such streaks. The trimming out of fire streaks is advisable, and will cause little loss in material. It is, of course, unnecessary to cull an entire sheet because of streaks unless they are numerous.

Broad Streaks

Broad streaks are generally 1 to 3 inches wide, and they are usually greenish, greenish brown, or purplish in color. They do not seem to be associated with insect work or any obvious defect. There is a sharp line of demarcation separating the bright and the discolored wood. The cause or causes of these broad streaks are not known. Some of them, and perhaps most of them from one mill, were merely narrow slices of blue-butted wood, or general discoloration, where the knife had just started to cut through such wood.

Although the specific gravity of such streaks is normal on the average, broad streaks at one of the mills were definitely weak (13 percent reduction in toughness). Their surface smoothness is generally like bright wood, but there is a tendency for them to split at the border of the bright and colored wood. It would be difficult to distinguish broad streaks from narrow bands of blue-butt, or what are here referred to as general discolorations. It is doubtful that these streaks need to be rejected.

Miscellaneous Streaks

Streaks of indefinite outline and of various light colors, generally lavender, green, or yellow, did not seem to be associated with insect work, or any other evident defect. They are characterized by a more gradual merging of the discolored into the bright in contrast to the sharp line separating the two in the case of fire streaks, insect streaks, and broad streaks. There are probably many causes of these streaks, since they do not constitute a single type.

The streaks were similar to normal wood in toughness and significantly higher in specific gravity at both mills, apparently due to deposits in ray cells. They need not be rejected.

Rot

All rots found were shades of brown, usually either a rust brown or dark brown, and often mottled or with definite small open pockets. The surface of a sheet cut from rotted wood, even if only in the incipient stage of decay, is almost always rough. Rots are caused by fungi, and several different decay fungi have been isolated from decayed yellow-poplar veneer. If fibers are dug out of a rotted sheet with a penknife, they will be found to be brash rather than splintery.

Even the incipient decayed wood studied in this work was definitely weak, and it was somewhat low in specific gravity. Any wood suspected of being rotted should be trimmed out.

Hints on Culling Yellow-poplar Veneer on the Basis of Color

1. Cull all veneer that is colored any shade of pure brown. There is commonly a purplish or greenish-brown band where blue-butted wood joins bright wood, and this should not be culled. All rots are colored brown, and practically all browns are weak, except normal tan heartwood and some purplish and greenish browns as noted above.

2. Streaks (discolorations about 3 inches or less in width) need not be culled for aircraft plywood but had best be trimmed out where this is easily practicable. The short black streaks called fire streaks should be trimmed out in all cases.

3. Do not cull general or mass colorations of the following colors: red, yellow, lavender, purple, gray, or any shade of green.

4. Discolorations that cause weakness almost always impart a rough surface to the sheet.

Table 1.--Relative toughness and specific gravity of the common colorations of yellow-poplar, as obtained from rotary veneer

Sheet basis[1]

Classification	Number of test sticks[2]	Number of colorations tested[3]	Mean specific gravity ratio[4]	Mean toughness ratio[5]
By type[6]				
Fire streak	4	4	[7]1.14	1.18
Miscellaneous streaks	23	6	[7]1.09	1.10
Sap stain[8]	131	35	1.02	[9]1.08
General discolorations	100	39	[7]1.04	1.01
Blue-butt	144	47	1.00	.96
Normal heart	92	29	1.01	.95
Insect streak	48	16	1.01	[7].93
Broad streak	66	21	1.00	.91
Rot	73	13	[9].97	[9].84
By color				
Yellow green	8	2	1.12	1.30
Gray	131	35	1.02	[9]1.08
Lavender	47	14	1.01	1.06
Black	31	14	[7]1.04	1.01
Dark green	93	33	[9]1.03	.98
Red	19	8	1.00	.98
Normal heart	92	29	1.01	.95
Purple	78	27	1.02	.94
Purple brown	49	15	1.01	.93
Brown - not rot	48	16	1.00	.91
Brown - rot	73	13	[9].97	[9].84
Buff	8	3	.95	.75

[1]All ratios for a given sheet or serial sheets of the same coloration were averaged, and the sheet average, weighted according to the number of pairs of sticks thereon, was used as basis of comparison.

[2]Each compared to an adjacent bright stick.

[3]This usually meant number of sheets, but in several cases there was more than one serially cut sheet from the same coloration. All pairs of sticks from a single coloration were averaged together.

[4]Ratio of specific gravity of a colored stick to its adjacent bright stick. Ratio of less than 1 means the colored sticks had, in general, lower specific gravities than the bright; more than 1, they were higher in specific gravity than the bright.

[5]Figured in the same manner as specific gravity ratios. Ratios of more than 1 mean colored sticks were tougher.

[6]These types of colorations are defined beginning on page 3 .

[7]Statistically significant at P=0.05 level. Difference from 1 reasonably reliable.

[8]Based upon four collections of material from three widely separated mills.

[9]Statistically significant at P=0.01 level. Difference from 1 very reliable.

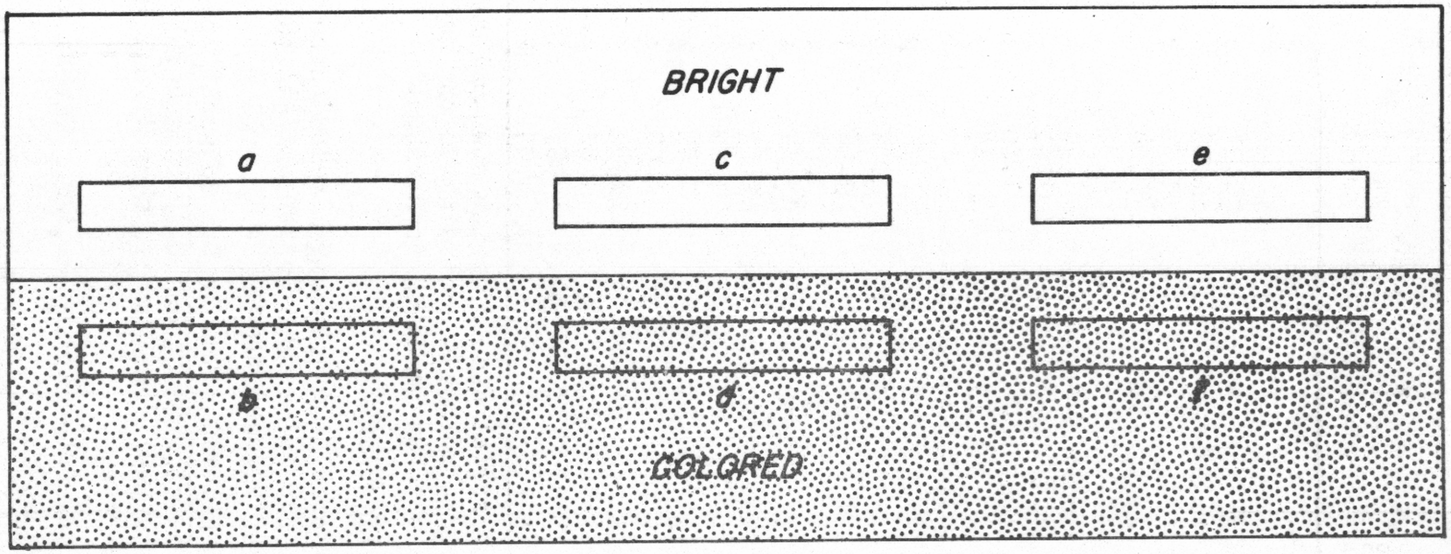

Figure 1. --The illustration shows how the colored pieces, b, d, and f, were cut from near the border of the colored and bright wood, so that each colored piece could be compared with one of the bright sticks, a, c, and e, not more than 1 inch away.

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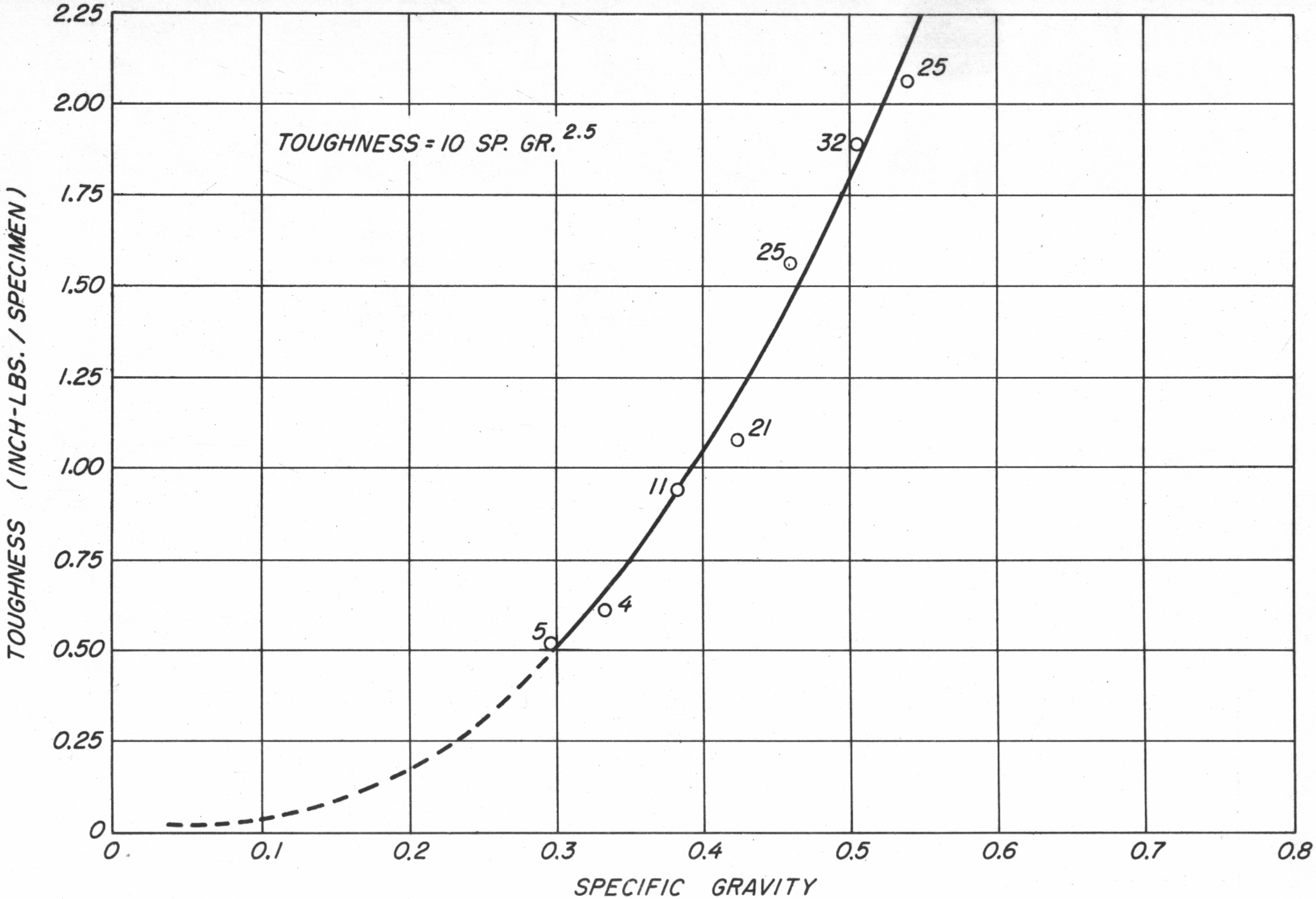

Figure 2. --The relation of toughness to specific gravity for 1/24-inch yellow-poplar bright sapwood veneer. (Based on oven-dry weight and volume at 65 percent relative humidity, 75° F.)

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