THE SIGNIFICANCE OF THE DISCOLORATIONS
IN AIRCRAFT VENEERS:
MAHOGANY AND KHAYA
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FOREST PRODUCTS LABORATORY
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SUMMARY

Toughness tests were made on specimens of mahogany and khaya veneer that included discolorations of various types.

Specimens were one-half inch wide and were of veneer of various thicknesses. Usually the full width was occupied by the discoloration in question. Toughness, or energy absorbed in breaking, of these specimens was compared with similar results on sound, nondiscolored specimens from the same sheets of veneer.

Army-Navy Aeronautical Specification AN-KN-F-511b does not enumerate all acceptable and nonacceptable defects or blemishes in veneer of various species and these tests were made to aid in inspection under this specification.

Numerical data presented in table 1 show the toughness values for discolorations of the several types expressed as percentages of similar values for sound material. These data are the basis for the following classification of discolorations:

A. Discolorations that indicate deficiency in toughness varying from none to moderate are not prohibited by the specification and may be disregarded.

Mold spots. Appearance -- small, round, yellow to orange or light brown spots. Occurrence -- rare.
Iron stain. Appearance -- purple blotches from contact of hot, wet veneer with iron or steel or from sap squeezed out in slicing by the knife or pressure bar. Occurrence -- common.
Mineral streak. Appearance -- small, dark brown patches scattered throughout the heartwood. Occurrence -- common in some logs but rare in general.
End stain. Appearance -- dark discolorations streaking in from ends of veneer. Occurrence -- occasional.
Worm streak. Appearance -- short, narrow, dark brown to black streaks originating at worm holes. Occurrence -- common.
Red streak. Appearance -- dark red streaks of variable length either alone or associated with gum streaks. Wood structure in streaks normal but impregnated with gum. Occurrence -- occasional.
White smudge. Appearance -- white powder in irregularly shaped spots or along growth rings. Occurrence -- rare in mahogany and absent in khaya.

B. Discolorations that although not specifically prohibited by the specification indicate sufficient deficiency in toughness to make their exclusion desirable.

Side stain. Appearance -- dark brown to black streaks of variable length near edges of veneer. Occurrence -- occasional.
Gum streak. Appearance -- dark red streaks, of variable length, associated with definite injuries. Wood structure abnormal, similar to included bark. Occurrence -- occasional. (Present practice is to clip out all gum streaks.)

Decay is, of course, prohibited by the specification and very little material showing evidence of decay was encountered in this study. Decay is indicated by white, gray, or grayish-brown discoloration.

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In this paper the name "mahogany" is used only with reference to the wood of Swietenia species, which are native to certain tropical regions of the western Hemisphere, and the name "khaya" is used to designate only the wood of the red khaya, often referred to as "African mahogany," which is native to the tropical regions of the west coast of Africa.

A survey of the color variation, normal and abnormal, in veneer of mahogany and khaya was made at 11 veneer and plywood plants in the United States and the defects and discolorations occurring in living trees and in logs were discussed with log buyers and importers. Samples of veneer for testing were collected at 5 plants.

All the mahogany veneer tested was of the species, Swietenia macrophylla, and was exported almost entirely from the port of Belize, British Honduras, and all the khaya tested was of the species Khaya ivorensis, and was exported from the ports of Grand Bassam, Ivory Coast, and Takoradi, Gold Coast, Africa. The results of the tests, however, may be applicable generally to veneer of Swietenia and Khaya species, respectively, regardless of origin.

NORMAL COLOR VARIATION IN MAHOGANY AND KHAYA VENEER

In mahogany the sapwood is usually pale yellow, but frequently is almost white. The heartwood when freshly cut is usually reddish-brown, but
at times is yellowish-brown or pinkish, always darkening with age or exposure to sunlight. In finished veneer or plywood it is usually dark red or reddish-brown, though occasionally it is dark yellow or yellowish-brown. Little, if any, sapwood is found in the clipped veneer and almost none in plywood, as it is ordinarily removed in the clipping and jointing process preparatory to taping or edge gluing.

In khaya the normal coloration is similar to mahogany, but, in general, the heartwood veneer is pinker when fresh and darker red when dry. The two woods are so similar in color and texture that sometimes it is difficult if not impossible, to distinguish between them.

In both mahogany and khaya, plain-or flat-sliced veneer is ordinarily uniform in color and lacks figure except for the ill-defined growth layers. Quarter-sliced veneer usually shows a definite ribbon figure, consisting of alternating dark and light-colored stripes, caused by distinct differences in the reflection of light from the bands of interlocked grain characteristic of both species.

DISCOLORATIONS IN MAHOGANY AND KHAYA VENEER

In mahogany veneer the discolorations most frequently observed are side stain, worm streak, mineral streak, gum streak, end stain, and red streak. Occurring less frequently are mold spots, white smudge, water stain, and iron stain.

In khaya veneer the same discolorations occur in about the same abundance with two exceptions; white smudge has not been observed or reported and end stain is more prevalent and often extends farther in from the end of the flitches.

Decay rarely occurs in veneer of either species, not because it is not present in the heartwood of the living tree, but because it usually is completely removed from the flitches when they are sawed from the log.

Between the felling of mahogany and khaya in the forests of the tropics and its arrival and use in United States veneer plants, there is an interval varying, at present, from several weeks as a minimum to several months as a maximum. Throughout this period conditions are usually excellent for the growth of wood-staining and rotting fungi and for the entrance of wood-boring insects, known to the lumber trade as worms. The action of all these organisms would be best controlled, if feasible, by speedy delivery from woods to mill. Removal of bark and in some instances of part of the sapwood hastens seasoning and deters fungus infection, but at the same time increases damage by checking. End coating of logs before shipment is occasionally practiced, but evidently the interval between felling and bucking and the application of the protective covering is sufficient to allow for infection by fungi. Judging by the frequency of occurrence of worm holes in logs and flitches in veneer plants, it is evident that none
of the measures now in practice is very efficient in preventing insect infestation. Some of the discoloration in logs, flitches, and veneer in United States mills is definitely a result of the action of fungi and insects that gain entrance to the wood during the interval from woods to veneer mill.

STUDY PROCEDURE

Of the veneer tested almost all of the mahogany was 1/28 inch in thickness, but a few pieces were 1/24 or 1/10 inch thick. Much of the khaya was 1/20 inch in thickness with most of the remainder 1/16 or 1/28 inch thick but with a few 1/12- or 3/32-inch pieces. All test pieces were 5 inches long and 1/2 inch wide and were cut as nearly parallel to the fiber direction as could be determined visually. Each discolored test piece was matched against a control piece of clear wood from the same sheet of veneer. All tests were made on a Forest Products Laboratory toughness testing machine. The specific gravity and relative toughness values for discolorations and their matched controls are shown in Table 1.

END STAIN

End stain is a general darkening of the heartwood at both ends of logs, its intensity and depth of penetration depending on the length of time elapsing between felling and utilization. Logs are usually butted off before flitching to remove the end checks and in this process part or all of the end stain is removed, that which sometimes shows in the veneer sheets being the innermost extension of the discoloration. The inner margin is extremely irregular or jagged, like greatly enlarged sawteeth of unequal length. Usually the line of demarcation is abrupt and well defined, but occasionally it merges gradually into normal color. Figure 1 shows end stain in khaya veneer.

The exact cause of end stain is not known. Usually, but not always, fungus mycelium is present profusely near the outer limits, toward the end of the veneer sheet, and rare or absent near the inner margin. It is probable that some discoloration would occur in the absence of staining fungi, for mahogany and khaya both darken perceptibly and uniformly when exposed to light and air. Actually, however, fungus infection almost invariably occurs. End stain was observed more frequently and usually penetrates deeper in khaya than in mahogany.

In mahogany, end stain resulted in an average reduction in toughness of 10 percent and in khaya 11 percent. In neither wood does there appear to be any objectionable characteristic of end stain other than the moderate reduction in strength. The fungus mycelium associated with it is probably that of staining organisms similar to the bluestaining fungi in native woods. Wood-rotting fungi may be present also but no recognizable decay was observed in end-stained veneer, and in the material tested the reduction in toughness was not sufficient to indicate the presence of decay.
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1/ Average toughness values are not given because the test pieces were not uniform in thickness.

2/ The ratio of the toughness of each discolored specimen to its matched control was computed and all ratios for each discoloration were averaged geometrically.

3/ Based on volume at test and oven-dry weight.

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SIDE STAIN

Side stain is a dark brown, occasionally almost black, heartwood dis-
coloration occurring in short patches or continuous throughout the length of
some veneer sheets. Generally it is just inside the heartwood zone but
frequently may be 2 inches or more into the heartwood. In quarter-sliced
veneer it appears only on the outer margin, but in flat-sliced veneer it may
appear on either or both edges of those sheets that are cut from the outer
portion of the flitch, or wherever the heartwood is adjacent to sapwood.
The streaks or patches of discolored wood are usually 1/2 to 1 inch wide,
ocasionally wider. Figure 2 shows side stain in mahogany veneer. It re-
sembles mineral streak but differs from it in containing a much greater pro-
portion of wound tissue. It undoubtedly is present in the wood of the living
tree and probably results from some type of injury common to tropical forests
such as sun scald, heat injury, insect infestation, or some bark disease.

Side stain in both mahogany and khaya resulted in a 25 percent
reduction in toughness. It is not evidence of decay, for fungus mycelium
is rare or lacking in such discolorations. It is probable that the strength
loss is correlated with the abnormal wood structure and the wound tissue
present. Side stain should be clipped out of aircraft veneer.

MINERAL STREAK

Common in the veneer from some logs but entirely absent in most, is
a discoloration which mill men call mineral streak. It shows up as small
patches darker brown in color than the surrounding wood. Most commonly
these patches are about 1/4 inch wide by 1 inch long, but occasionally they
are as large as 1 inch wide and 3 inches or more long. Figure 3 shows
mineral streak in mahogany veneer. If mineral deposits are present in
these patches, they are not heavy enough to increase appreciably the spe-
cific gravity of the wood. Carbon dioxide bubbles are not formed when
dilute acid is applied to them. Microscopic examination shows wound tissue
in the discolored patches so it is probable that they result from some small
wound that completely heals in a short time. Fungus mycelium is ordinarily
absent.

In mahogany, mineral streak was the same in toughness as the controls
and in khaya there was only a 3 percent reduction in toughness. Little if
any significance can be attached to its occurrence in veneer of either
species.
WORM STREAK

Worm streaks are narrow, elongated, dark brown to brownish-black areas originating at worm holes. They are common in the outer heartwood of nearly all logs and occasionally are found deep in heartwood. Most of the worm holes in the outer heartwood are small, under 1/8 inch in diameter. Those in the central heartwood are larger, sometimes up to 1/2 inch in diameter. The streaks are always narrow, usually about 1/4 to 1/2 inch wide but occasionally wider, and follow the direction of the wood elements. Figure 4 shows worm streaks in mahogany. Fungus mycelium is abundant in worm streaks and in addition considerable mineral and gum is deposited in all of the wood elements, as shown by the increase in specific gravity.

In mahogany, worm streaks were 3 percent weaker in toughness and in khaya they were slightly stronger than the matched controls. There is little cause for discrimination against worm streaks unless the size and number of worm holes makes the veneer not acceptable.

GUM STREAK

Gum streak, sometimes called blood streak, hard streak, or bony streak, is a dark-red, elongated discoloration, parallel to the grain, varying in length from a few inches to the full length of a sheet of veneer. It is common in some logs, rare or absent in others, and consists of lysigenous gum canals in callus tissue that originated as a result of a severe injury to the cambium. Short gum streaks originate at branch stubs, bird pecks, and mechanical injuries of various types. Long gum streaks probably are initiated by lightning injury, severe sun scald, or injuries made by falling trees scraping off the bark over extensive areas. When the gum is old and dried, it becomes brittle and resembles included bark. Veneer containing gum frequently checks parallel to the grain along the edge of the streak. A rather narrow gum streak in mahogany is shown in figure 5, A.

It was almost impossible to secure gum streaks the full width of the test pieces without having them break in handling. Narrow streaks, usually about 1/4 inch wide, were included in the 1/2-inch test specimen. Even so, they were 30 percent weaker in toughness in mahogany and 18 percent in khaya. Gum streaks should be clipped out of aircraft veneer.

RED STREAK

Red streaks are usually long, narrow discolorations similar in many respects to gum streaks but differ from them in having the original wood only slightly altered in structure, except that it is impregnated with a dark-red gummy substance. Figure 5, B shows a red streak in mahogany.
with a very narrow gum streak adjoining it. In general, red streaks have
the same origin as gum streaks, but the causal injury was not severe enough
to create an open wound with callus formation and free-gum exudation. In
slicing veneer, as the knife approaches a typical gum streak, there
frequently will be several sheets of veneer containing red streak before
the gum streak shows clearly, indicating the definite relationship between
the two defects.

In mahogany, red streaks were 15 percent weaker in toughness and in
khaya 16 percent. They should be discriminated against for all highly
stressed structures but should otherwise be acceptable.

MOLD SPOTS

Mold fungi will appear in a few days on veneer which is kept wet and
warm after slicing. On mahogany and khaya such molds usually cause small,
round, yellow to orange or light brown spots, usually about 1/4 to 1/2 inch
in diameter. On mahogany, mold spots were associated with a 4 percent
reduction in toughness, but ordinarily it is to be expected that no weakness
will result. Tests were not run on khaya.

WATER STAIN AND IRON STAIN

Sheets of piled wet veneer will often dry out from the ends before
they are run through the drier. This sometimes gives them a slightly
lighter, bleached appearance, which is called water stain. Mahogany with
water stain was 1 percent stronger in toughness, but in general there
should be no difference between it and normal veneer. Tests were not run
on khaya.

A purple-colored stain causing irregular blotches frequently occurs
in both mahogany and khaya. It results from the contact of hot wet veneer
with iron or steel or from concentrations of the sap squeezed out in
slicing and dripping off the knife or pressure bar. Iron stain is of no
significance with respect to strength, being 3 percent stronger than normal
mahogany in the tests. Khaya was not tested.

WHITE SMUDGE

White smudge is a discoloration in mahogany veneer, rare in occur-
rence but very noticeable when present. It consists of a white deposit,
resembling chalk or powdered limestone, in irregularly-shaped spots, vary-
ing in size from a square inch to several square feet, or extending along
certain growth rings. It definitely is not lime but is composed of a
crystalline water-soluble organic compound of unknown composition. It is
not visible in the log or flitch or on wet veneer but apparently crystallizes in the vessels or pores and on the surface of veneer during the drying process. There probably is a definite correlation between the concentration of the compound in solution in the sap of a log and the amount of white powder which appears on the surface after the wood is dried; the greater the concentration, the denser the white smudge. It is reported as occurring more commonly in mahogany from Peru or Cuba than in that from Central America, and two veneer plants report it as most severe in veneer from large, dense, dark-red logs. It occurs in low density logs also but apparently is concentrated in the denser parts of them. It has not been observed or reported in khaya veneer. With only 21 tests as a basis, white smudge in mahogany was associated with a 10 percent reduction in toughness.

DECAY

Decay in mahogany and khaya veneer was found too infrequently to secure samples for testing. When observed, it was always some shade of white, gray, or grayish brown, easily distinguishable by color alone from any of the non-decay discolorations. In mahogany, decay was observed in the outer heartwood in close association with worm holes (Figure 6A) and was grayish brown in color and crumbly in texture. A light-gray decay originating at a wound and associated with red streak was occasionally encountered (Figure 6B). In khaya a white pocket rot in the central heartwood was found several times (Figure 7A). The wood in the pockets is gray to white, very soft, and the wood between the pockets is apparently sound. A gray and brown mottled rot streaking in from the butt end of one flitch was observed once (Figure 7B).

All veneer showing recognizable decay of these or any other types should be rejected for aircraft use. By the time decay is recognizable by color in both mahogany and khaya it has, in all observed cases, greatly reduced the strength of the affected wood.
Figure 2.—Side stain in mahogany veneer. A, About one-third natural size. B, Natural size.
Figure 4.—Worm streaks in mahogany veneer. Natural size.

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Figure 5.—A, Gum streak in mahogany veneer. Natural size. B, Red streak in mahogany veneer with a narrow gum streak at one side. Natural size.
Figure 6.--Types of rot observed in mahogany veneer. A, Grayish-brown rot associated with worm holes. Natural size. B, Light gray rot originating at old wound. Natural size.
Figure 7.—Types of rot observed in khaya veneer. A, White pocket rot. Natural size. B, Gray and brown mottled rot. About one-half natural size.