PRESENCE OF TENSION WOOD IN MAHOGANY IN RELATION TO LONGITUDINAL SHRINKAGE

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PRESENCE OF TENSION WOOD IN MAHOGANY IN RELATION TO LONGITUDINAL SHRINKAGE

By

MAXON Y. PILLOW, Technologist

Forest Products Laboratory,[1] Forest Service
U. S. Department of Agriculture

Summary

Some mahogany lumber has been found to contain tension wood and to shrink excessively along the grain. Highly significant correlation has been shown between longitudinal shrinkage and the amounts of gelatinous fibers that characterize tension wood. It has been concluded that differential shrinkage caused by irregular distributions of tension wood sets up internal stresses, and that as a result of such stresses warping frequently occurs in pieces being processed from mahogany lumber.

Introduction

This report presents a study of the occurrence and longitudinal shrinkage of tension wood in mahogany lumber. It is a continuation of other studies at the Forest Products Laboratory on characteristics and behavior of tension wood in hardwood species.

The previous studies[2] showed that the presence of tension wood is associated with much greater shrinkage along the grain than usually occurs in normal wood. Differences in shrinkage in boards that include both these types of wood frequently cause serious warping when the lumber is processed for furniture parts. The present study was made to determine variability of longitudinal shrinkage of mahogany lumber and also whether this property was related to amounts of tension wood in the test specimens.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Occurrence of Gelatinous Fibers and Their Effect on Properties of Hardwood Species. Virginia Akins and Maxon Y. Pillow. Proc. of For. Prod. Res. Soc. June 1950.

Tension wood that occurs on the upper or tension side of some leaning hardwood trees, is characterized by the presence of gelatinous fibers. These fibers can be readily detected under the microscope by their reactions to certain dyes and reagents. Frequently, they are found in isolated growth rings; but sometimes they are present in several consecutive rings.

Test Material

The determinations of longitudinal shrinkage were made on specimens cut from six mahogany boards that had originated in Mexico. Examinations showed that four of the six boards included varying amounts of tension wood, and that the remaining two had the typical structure of mahogany. The rough-sawed boards with tension wood were characterized by gelatinous fibers that projected from the surfaces, from which they had been partially torn loose in groups by the saw teeth. Such boards had a fuzzy appearance (fig. 1) in contrast to that of sawed surfaces of normal mahogany that did not have projecting fibers (fig. 2). This difference was in accord with previous observations that the presence of tension wood in other species was associated with fuzzily sawed surfaces.[2]

The boards available for the test specimens had relatively straight grain, except for some interlocked grain that was present in each one. Interlocked grain has been found to be characteristic of much mahogany lumber. Slopes of interlocked grain were, however, relatively slight, and they were therefore not considered to have an appreciable effect on longitudinal shrinkage.

Test specimens were about 7/8 by 1 by 9-1/2 inches. Each of the six boards was first planed on both sides and jointed on one edge. As many specimens as possible were then ripped from each board.

Each test specimen was designated by a system of two numbers that represented the boards and the specimens within each board. There were available for use in this study 35 specimens from 4 boards that contained tension wood and 13 specimens from 2 boards that had the normal structure of mahogany.

Procedures for Determinations and Examination

Because the lumber had been partially air-dried, the specimens were soaked in distilled water until lengthwise measurements indicated that they had reached their approximate maximum swelling. This swollen condition, reached in about 48 hours of soaking, was considered to be practically the same as the green condition of the wood.

The lengths of the soaked specimens were measured to the nearest 0.001 inch with a dial micrometer. After this measurement the specimens were dried at 80° F. and at successive relative humidities of 80, 65, and

30 percent over a period of about 3 weeks. Finally, the specimens were dried at about 220° F. to constant weight and then remeasured. The percentage of longitudinal shrinkage was based on soaked length of the specimens.

The presence of gelatinous fibers and their structural characteristics were determined by examinations with a compound microscope. Most of these examinations were made on temporarily mounted microtome sections. Gelatinous fibers were readily identified by their differential coloring when treated with chloriodide of zinc. The peculiar inner layer characteristic of gelatinous fibers was colored blue or purple, depending on the concentration of chloriodide of zinc, but the outer layers of these fibers and the entire cell walls of normal mahogany fibers were colored yellow or light brown.[2]

Relatively simple technique was usually found satisfactory to identify gelatinous fibers in the temporarily mounted transverse sections of mahogany. Such sections were cut on a sliding microtome from small blocks of wood that had been softened for sectioning by being boiled in distilled water until they sank, after which they were stored in 70 percent alcohol until sectioned. The sections were placed on an ordinary microscope slide, washed two or three times with distilled water, and were then flooded with the chloriodide of zinc and allowed to stand for 15 to 30 seconds. The reagent was then drained off, a fresh drop of it was added, and a cover glass was placed over the section. Examinations to detect the presence of gelatinous fibers were made at magnifications of about 100, 200, and 400 times. The sections showed the respective reactions with chloriodide of zinc for normal fibers and for those with the gelatinous inner layers. The useful life of such preparations usually did not exceed 4 to 5 hours.

From recent investigations of fluorescent materials, a new technique was developed at the Forest Products Laboratory by which it was possible to obtain relatively permanent preparations, whose useful life was found to be many months or possibly years. In this study of mahogany, it was found that normal fibers and inner layers of gelatinous fibers showed differential fluorescence in ultraviolet light when treated with a proprietary dye known as "Calco Condensation Red BX." Examination in ultraviolet light showed a yellow fluorescence of the dye in normal cell walls, but the inner layers of gelatinous fibers fluoresced the normal blue color of the wood without addition of material reactive to ultraviolet light. The fluorescent material appeared to be absorbed by typical fiber structure, but to be loosely held by the inner, gelatinous layer so that most of it was washed out during dehydration of the sections with alcohol.

Results of Examinations and Determinations

Most of the specimens from tension-wood boards were fibrous in surface appearance (fig. 3) after being ripped with a special saw that ordinarily left relatively smooth surfaces (fig. 4) on pieces of normal mahogany. Roughness and fuzziness of surfaces had been previously observed as a characteristic of pieces that contained tension wood.[2] End-grain surfaces of tension wood that had been planed had relatively dark zones (fig. 3) in which the gelatinous fibers were present. On the other hand, similar surfaces of normal mahogany were uniform in color (fig. 4). Thus fuzziness and relatively dark or intense color of certain zones on the end grain were visible characteristics that signified the presence of tension wood in mahogany.

Variations in Shrinkage

Averages and ranges of values for longitudinal shrinkage of the specimens from each board are shown in table 1. The average shrinkage of all specimens from the tension-wood boards was much higher than that of the normal-mahogany boards. These averages were 0.457 and 0.149 percent, respectively, of the soaked length of the tension-wood and normal specimens. The range of shrinkage values for tension-wood boards was 0.105 to 0.641, and the range for normal boards was 0.116 to 0.179. The latter range was within what is usually considered to be the normal range of longitudinal shrinkage for most species of wood, namely, 0.1 to 0.3 percent.[3] One board that was classified as tension wood also included, however, some normal specimens that had longitudinal-shrinkage values of 0.105 to 0.221 percent. These normal specimens accounted for a few low values from the tension-wood boards; and they also accounted for the overlapping in the ranges of the values for specimens from tension-wood boards and from normal boards.

Figure 5 shows the frequency distributions of the longitudinal-shrinkage values for specimens from boards that contained tension wood and for those from normal boards. The distribution pattern of shrinkage values for tension wood was asymmetrical with concentrations in the higher values, while values for normal mahogany were distributed symmetrically with a concentration near the average.

The standard deviation (0.1446) for the values of lengthwise shrinkage of the tension-wood specimens was larger than that (0.01595) for those of the normal specimens. The coefficient of variation,[4] which was used to compare the respective variability of the shrinkage values in terms of averages of tension wood and of normal wood (standard deviation/average x 100), emphasized the great variability of longitudinal shrinkage in tension wood. The values of this coefficient were found to be 31.6 percent for tension-wood boards and 10.9 percent for normal boards. This difference indicated that tension-wood boards had nearly three times the variability of normal wood.

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[3] Longitudinal Shrinkage of Wood. Arthur Koehler. Forest Products Laboratory Report No. R1093. Revised September 1946.

[4] Statistical Methods. George W. Snedecor. Ames, Iowa, 1946.

Structure of Tension Wood

Examinations of the end-grain surfaces of the tension-wood boards from which the test specimens were cut, indicated relatively wide variability in the amount and distribution of tension wood. These surfaces showed that zones of dark-colored tension wood frequently were not continuous in successive growth rings, but that such zones were interspersed with normal wood. The zones of tension wood were closely associated with fuzziness of the originally sawed surfaces (fig. 3). Such fuzzy areas included about one-half to two-thirds of the width of the boards (fig. 1). Gelatinous fibers were found in wood having fuzzy surfaces, in dark-colored zones that were included in some growth rings, and in wood having excessive longitudinal shrinkage. In general, relatively large values of longitudinal shrinkage also were associated with occurrence of fuzziness of the sawed surface of the board.

The examinations with a microscope of tension-wood specimens showed variability in amounts and characteristics of the gelatinous fibers in tension wood of mahogany. In some microscopical sections with numerous gelatinous fibers, the inner layers of the fiber walls were usually relatively thick and were frequently one-half or more of the total thickness of the cell wall. In other sections with only a few gelatinous fibers, the inner layers were usually appreciably thinner, and were sometimes a barely distinguishable line. Thus, variability in structure of tension wood was observed, not only in the amounts of gelatinous fibers present in a given area of a cross section, but also in the thickness of the inner layers of fiber walls.

The amounts of gelatinous fibers were estimated in the entire cross section of each test specimen. These estimates were based on frequencies of gelatinous fibers, such as scattered, moderately abundant, or solidly grouped, in the areas of the fibrous tissue of the sections. Such estimates were further weighted on the basis of gross distribution of tension wood; that is, whether it occupied approximately 1/4, 1/3, 1/2, 2/3, or 3/4 of the areas of the cross sections of the specimens. From the relative frequency of gelatinous fibers within tension-wood areas and from the fractions of the section occupied by these areas, a product was calculated as a percentage value. This value was calculated for all specimens from the four tension-wood boards in which gelatinous fibers were detected by microscopical examination. In 4 of the 35 specimens from these boards, however, no gelatinous fibers were detected.

Correlation of Structure and Shrinkage

Longitudinal-shrinkage values of the test specimens were found to be reasonably well correlated with numbers of gelatinous fibers. The correlation coefficient[4] for these data was found to be $r = 0.844$, which indicated a highly significant correlation between longitudinal shrinkage and amounts of gelatinous fibers. This relationship appeared to be a linear one for these specimens, as was indicated by the data plotted in figure 6.

Discussion of Results

The data showed wider variability in longitudinal shrinkage of the specimens with tension wood than in that of the specimens with normal wood. Such variations in shrinkage along the grain of some boards accounted for the occurrence of differential stresses in mahogany lumber with tension wood having irregularly distributed and varying amounts of gelatinous fibers. Such internal stresses, when unbalanced as the boards were ripped, has been observed to result in warping of the pieces. The balance of stresses in lumber was also disturbed by pieces being planed and shaped.

The data of this study showed that longitudinal shrinkage increased as amounts of gelatinous fibers increased in the specimens. These values tended to follow a straight-line relationship. Although these data showed highly significant correlation between longitudinal shrinkage and amounts of gelatinous fibers, a linear relationship may be somewhat questionable because of an insufficient number of specimens in the lower range of estimated amounts of gelatinous fibers. It is possible that this relationship between shrinkage and amount of gelatinous fibers may follow a curve that rises rapidly in small percentages of gelatinous fibers and tends to flatten in the larger percentages. The shape of such a relation of longitudinal shrinkage to amounts of gelatinous fibers can be determined only by study of additional material that has small amounts of these fibers.

Conclusions

The results of this study lead to the following conclusions.

1. Tension wood occurs in various positions and amounts in mahogany lumber. It is characterized by fuzzy surfaces and the presence of gelatinous fibers.

2. Excessive and erratic longitudinal shrinkage is characteristic of mahogany lumber that contains tension wood.

3. Warping of pieces of mahogany lumber that contain tension wood is caused by internal stresses along the grain that result from variations in longitudinal shrinkage of tension wood and normal wood.

4. Variations in longitudinal shrinkage are correlated with numbers of gelatinous fibers, and, within this study, this relationship appeared to be linear.

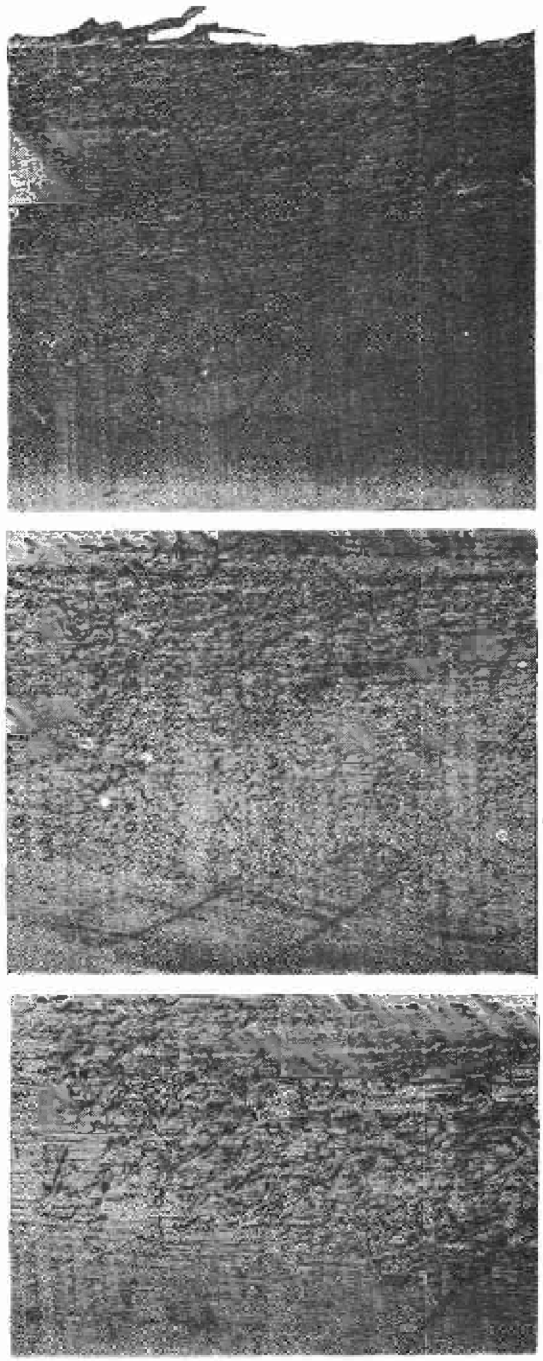
5. Further study is necessary on the relation of longitudinal shrinkage to numbers of gelatinous fibers, particularly in material having few of these fibers.

Table 1.--Average and range of oven-dry values for longitudinal shrinkage as percentages of soaked length of specimens cut from mahogany boards that included tension wood or had typical structure.

Kind of structure	Designation of board	Number of specimens	Longitudinal shrinkage		
			Average	Range	
				Minimum	Maximum
			Percent	Percent	Percent
Tension wood	1	7	0.561	0.357	0.641
Do.......	2	9	.532	.262	.620
Do.......	3	9	.337	.105	.588
Do.......	7	10	.424	.315	.483
Typical	4	6	.142	.116	.158
Do.......	5	7	.152	.137	.179

Figure 1.--Unplaned mahogany boards with the fuzzy surfaces that indicate the presence of tension wood.

(ZM 81654 F) ....



ZN 81604 F

Figure 2.--Unplaned mahogany boards with the relatively smooth surfaces characteristic of normal wood.

(ZM 81655 F) ....

Figure 3.--Longitudinal shrinkage specimens (above) with planed end-grain surface of a board (below) including tension wood from which the specimens were cut. Note roughness and stringy, fibrous attachments to edges of sawed surfaces of the specimens and relatively dark color of the zones of tension wood, as well as fuzziness at the top edge of the end-grain piece.

(ZM 81659 F)

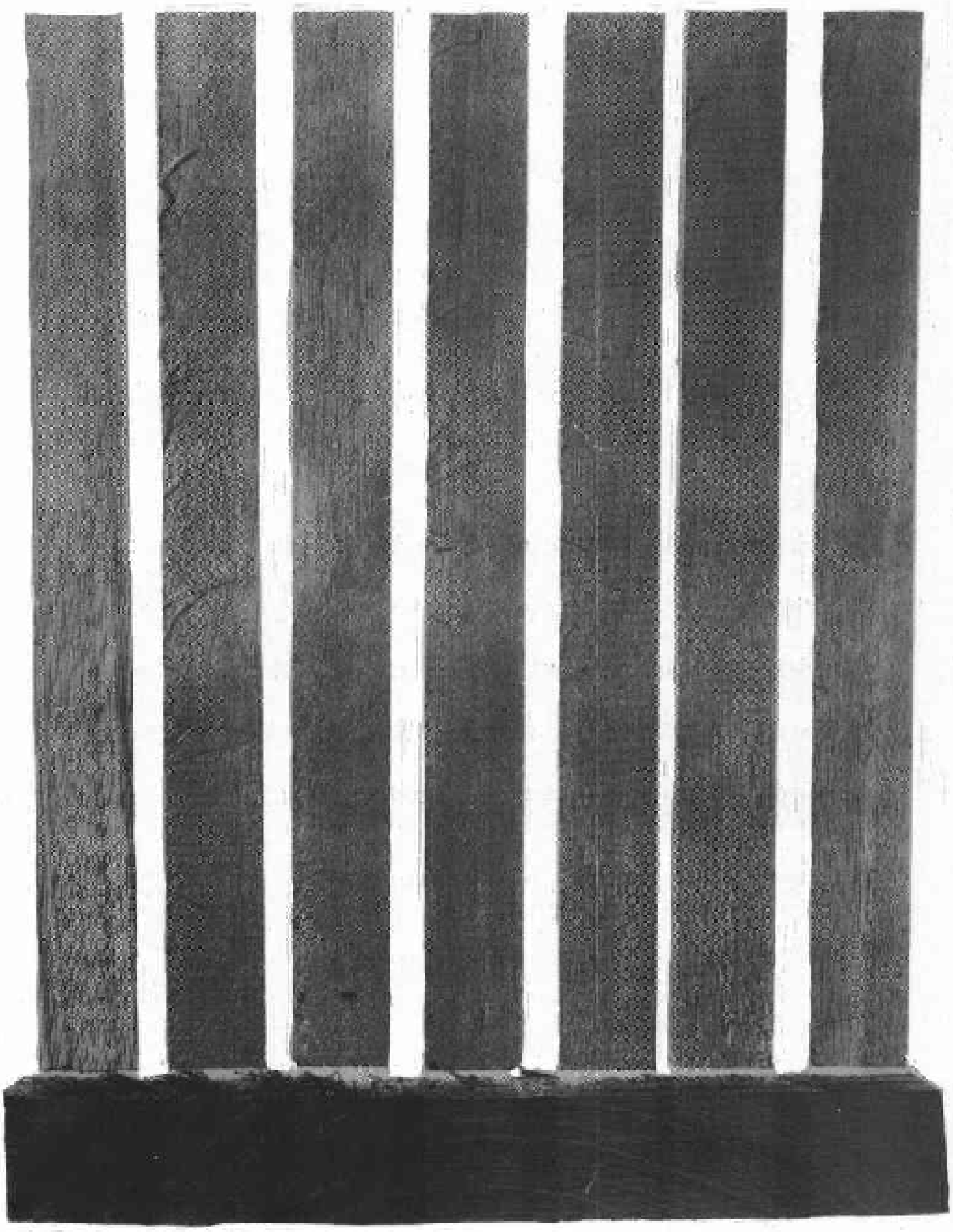
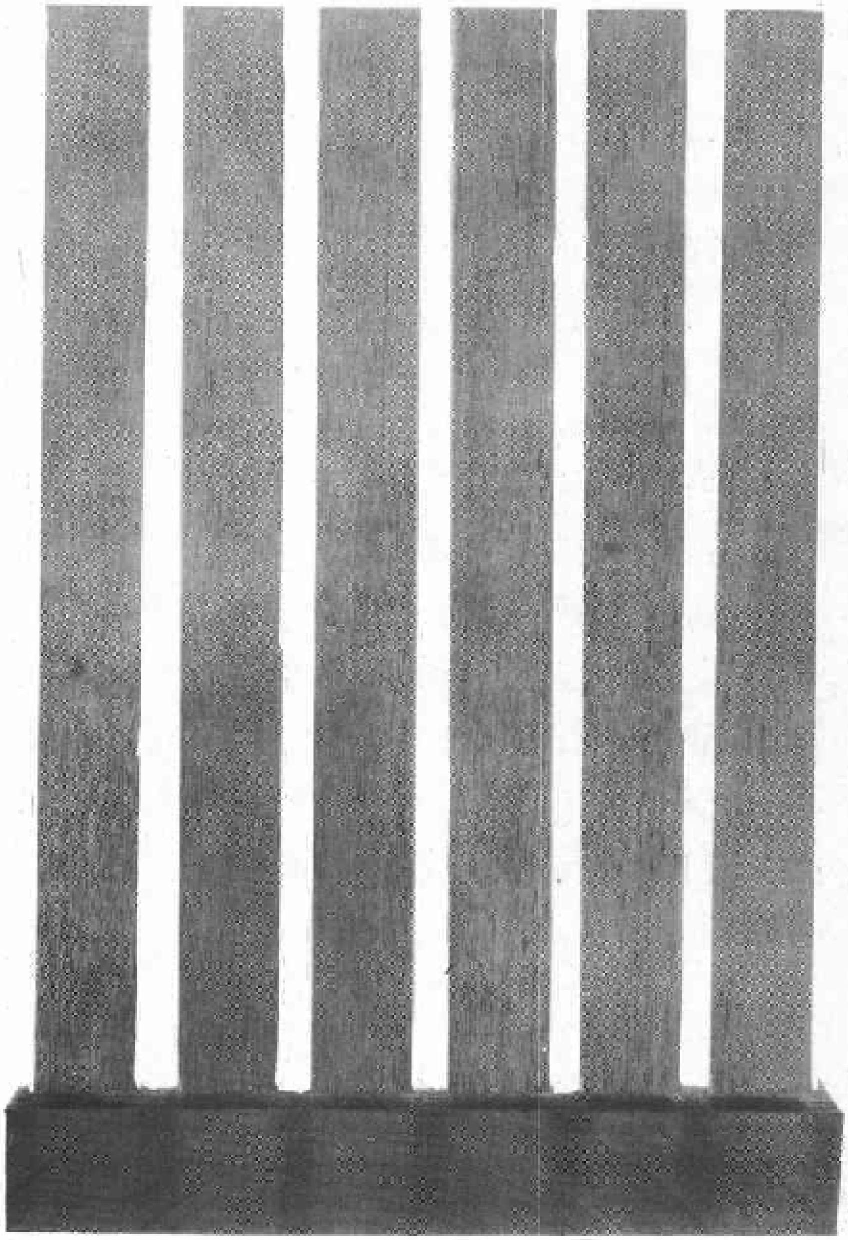


Figure 4.--Longitudinal shrinkage specimens (above) with planed end-grain surface of a mahogany board (below) with normal structure from which the specimens were cut. Note relative smoothness of the surfaces of the specimens and uniformity of color of the end grain.

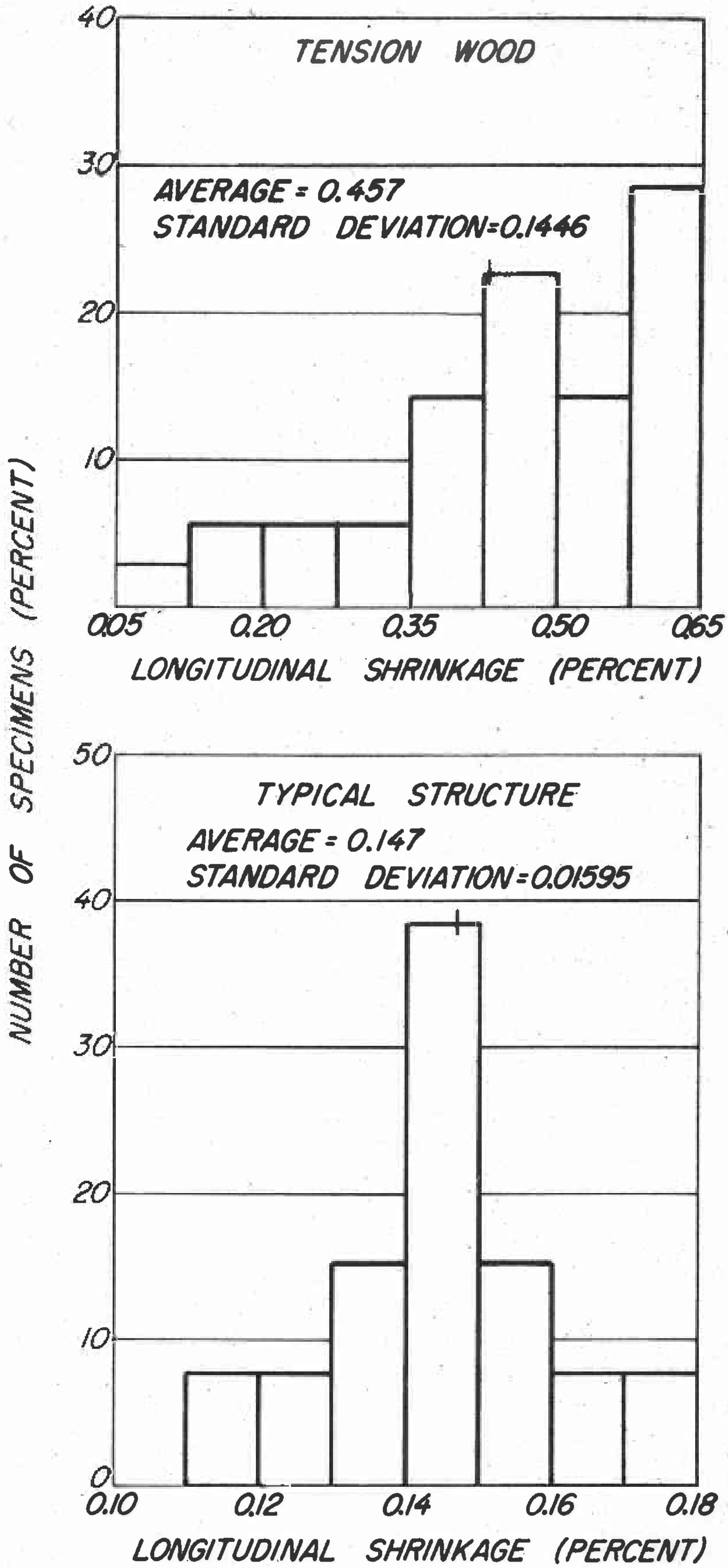
(ZM 81658 F) ....



[redacted]

Figure 5.--Frequency distributions of values for longitudinal shrinkage of specimens from boards including tension wood and from others with normal mahogany. The ranges of each group of specimens were plotted on different scales to facilitate direct comparison of the patterns of distribution.

(ZM 84691 F) ....

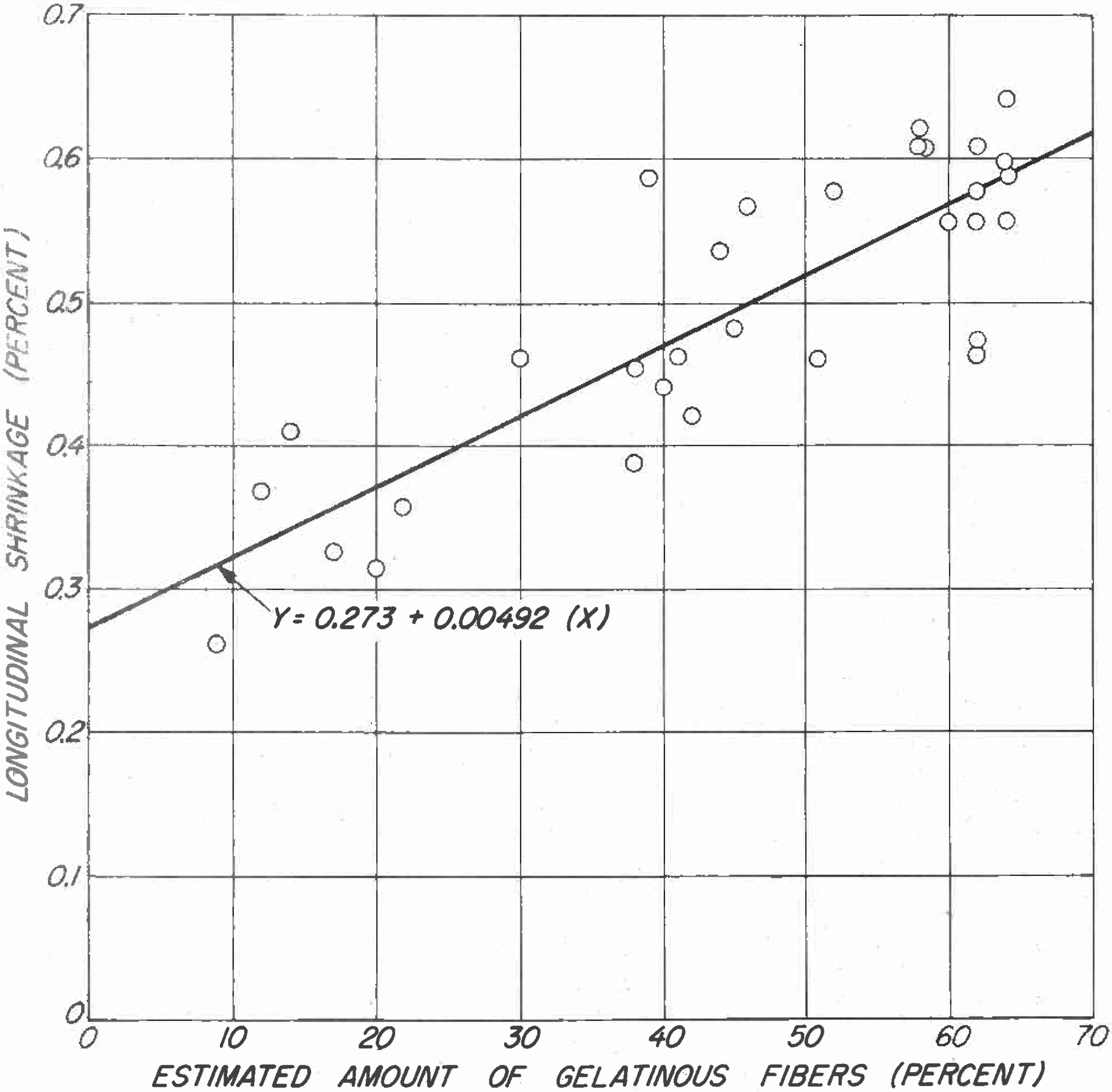


TENSION WOOD
AVERAGE = 0.457
STANDARD DEVIATION=0.1446
40
30
20
10
0.05
0.20
0.35
0.50
0.65
LONGITUDINAL SHRINKAGE (PERCENT)
NUMBER OF SPECIMENS (PERCENT)
TYPICAL STRUCTURE
AVERAGE = 0.147
STANDARD DEVIATION = 0.01595
50
40
30
20
10
0
0.10
0.12
0.14
0.16
0.18
LONGITUDINAL SHRINKAGE (PERCENT)

Z M 84691 F

Figure 6.--Relationship of longitudinal shrinkage to amounts of gelatinous fibers in tension-wood specimens of mahogany.

(ZM 84692 F)



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
LONGITUDINAL SHRINKAGE (PERCENT)
Y = 0.273 + 0.00492 (X)
0
10
20
30
40
50
60
70
ESTIMATED AMOUNT OF GELATINOUS FIBERS (PERCENT)

Z M 84692 F