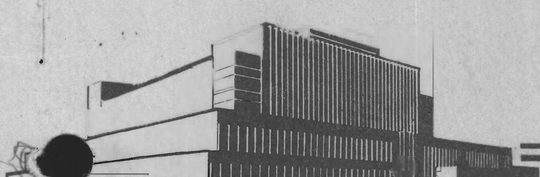
(Report) 2233

A CONCEPT OF INTRINSIC WOOD QUALITY, AND NONDESTRUCTIVE METHODS FOR DETERMINING QUALITY IN STANDING TIMBER

October 1961

No. 2233



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

A CONCEPT OF INTRINSIC WOOD QUALITY, AND NONDESTRUCTIVE METHODS FOR DETERMINING QUALITY IN STANDING TIMBER[1]

By

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Abstract

This paper presents a concept of wood quality. The heart of the concept is: Quality is the resultant of physical and chemical characteristics possessed by a tree or a part of a tree that enable it to meet the property requirements for different end products. In other words, the intrinsic quality of wood evaluated solely in terms of its suitability for various products or end uses.

A number of the more important wood-quality indicators are discussed, with emphasis upon the relationship between wood characteristics and property requirements. The following are considered: Wood density, ratio of summer-wood to springwood, fine structure, chemical composition, paintability, gluing, sapwood thickness, nonuniform growth, growth rate, distinctive figure, compression wood, tension wood, and compression failures.

Included are brief discussions of the need for a better concept and wider appreciation of wood quality, the ways in which wood quality can be improved, and methods and results of wood-quality evaluation in standing timber.

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[1] Presented by Dr. Edward G. Locke, Director of the U. S. Forest Products Laboratory, at the 13th Congress of the International Union of Forest Research Organizations (Section 41, Mechanical Conversion) September 10 to 29, 1961, in Vienna, Austria.

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

Introduction

The term wood quality, through misuse and lack of a generally accepted definition, may mean many things to many different people. However, at the U. S. Forest Products Laboratory we have developed over a period of 50 years what we believe is a rather clear-cut, meaningful, and technically adequate concept of wood quality. We have made every effort to convey our ideas to others, and to see that wood quality receives the consideration it deserves in the fields of forest genetics and forest management, and by the wood processing industries.

We are indeed pleased that in the last few years more and more geneticists have accepted wood-quality improvement as one of the primary objectives of their selection and breeding programs. In fact, some of the best research on wood quality in this country is now being done by the geneticists. Unfortunately, however, most forest managers and lumbermen still hold to a crude and no longer adequate concept of quality that originated back in the heyday of the lumber industry. Few of them have started thinking of wood quality in terms that made sense in today's technically oriented, increasingly choosy, and highly competitive consumer markets.

A Concept of Quality

We are not prepared to offer a definition of timber quality that would be all-inclusive, unambiguous, and completely satisfactory to all persons for all purposes.

We are, however, prepared to present the concept of timber quality formally adopted by the U. S. Forest Service during a Timber Quality Conference held at the Forest Products Laboratory 4-1/2 years ago. We had something to do with the development of this concept, and it pretty well reflects our own ideas on the subject.

We consider quality in relation to an individual tree or component segments thereof, rather then to a forest stand, though we recognize that there is utility or use value in forest stands. We consider only the wood itself, and not the aesthetic, recreational, wildlife, or watershed benefits associated with the existence of the tree. Though quality measures are applied principally to timber in its present condition, the concept does not rule out the potential quality attainable by added growth on a young tree.

Our concept of quality is based entirely on the relationship between the physical, chemical, and other characteristics possessed by a tree or a part of a tree and the properties required or desirable for the end products made of wood. This concept rules out consideration of accessibility, operability, markets, cost of harvesting, or cost of utilization for specific end products. It in no way belittles the importance of these other considerations, however, in the formulation of utilization and management decisions. The properties required or desired for the various end products are those associated with the present state of technology, completely divorced from long-obsolete customs and traditional practices.

Briefly stated, the heart of our concept is: Quality is the resultant of physical and chemical characteristics possessed by a tree or a part of a tree that enable it to meet the property requirements for different end products. In other words, the intrinsic quality of wood is evaluated solely in terms of its suitability for various products or end uses.

Wood-Quality Indicators

Now, what are the characteristics of wood, in addition to soundness, size, clearness, and the like, that determine its suitability for various end uses? A discussion of some of the more important ones follows.

Wood Density

The density of wood--expressed as weight in pounds per cubic foot or as specific gravity--is a direct measure of the amount of wood substance in a cord of pulpwood, a piece of lumber, or a sheet of veneer. Accordingly, density is a simple, practical, and certainly the most commonly used index of the general suitability of wood for many of its important uses. Density, however, is highly variable because it is the result of the whole aggregate of environmental and inherited factors that effect wood formation in a tree.

Our report on standard terms for describing wood characteristics (5)[3] classifies the average specific gravity among species in 10 categories from extremely light, less than 0.20, to extremely heavy, greater than 0.86. There is also considerable variation in specific gravity within species, and within groups of such closely related species as the southern pines. For example, systematic mass sampling of standing pine trees in Mississippi by

[3]Underlined numbers in parentheses refer to Literature Cited at the end of this report.

increment cores (7) showed that specific gravity ranged from 0.30 to 0.85 for the five species sampled (fig. 1).

The relationship between wood density and yields of kraft pulp from southern yellow pines is practically a straight line. In general, for every 2-pound increase in wood density there is produced nearly 1 pound more of pulp. Stated another way, a cord of high-density southern pine wood will yield about twice as much kraft pulp as a cord of low-density pulpwood. The same general relationship between wood density and pulp yield holds for all species, although the exact relationship may vary with the kind and severity of processing.

There is also a high degree of correlation between specific gravity and the strength properties of wood (4). Figure 2 shows an example of the typical strength increases with specific gravity for second-growth longleaf pine. Specific gravity, therefore, is a primary factor in the segregation of structural-grade timbers that command premium prices in the lumber market, and also in the selection of material for high-grade piling, transmission poles, and other uses where strength is of major importance (6). For uses such as ladders, where safety is an important consideration, the manufacturing codes specify that "low-density wood shall not be used" (1).

On the other hand, for certain products, such as particle boards in the 35-pound (per cubic foot) class preferred by the furniture industry for core stock, very low-density wood is essential. In recent studies at the Forest Products Laboratory, it was found that particle boards made of wood particles or flakes with a specific gravity of 0.3 were ideal from the standpoint of strength, stiffness, and dimensional stability as well as weight. Accordingly, forest geneticists should consider selection and breeding for a combination of low density and fast growth, starting with willow, cottonwood, aspen, hybrid poplar, and other species that are otherwise suitable for this important use.

Ratio of Summerwood to Springwood

Another key feature is the proportion of summerwood to springwood in the annual growth ring. In the softwoods particularly, springwood consists of relatively large-diameter, thin-walled, low-density fibers, whereas the summerwood is made up of smaller, thicker walled, higher density fibers. The specific gravity of the aggregate annual rings, therefore, increases with the percentage of summerwood, especially in the denser softwoods such as Douglas-fir and the southern yellow pines.

Figure 3 shows how specific gravity varies with the percentage of summerwood in complete annual rings, and with separated springwood and summerwood portions thereof (13). In part, at least, these relationships account for the general trend toward increasing specific gravity with age of southern pines as shown by the Mississippi wood density survey.

Differences in the fiber anatomy of springwood and summerwood affect pulp properties as well as specific gravity and, thereby, pulp yields. For example, pulp sheets made experimentally of practically pure springwood from southern pines tend to felt better, are denser, and more opaque than those made of summerwood. This is because the thin-walled springwood fibers readily collapse to a ribbon-like form, in contrast to the summerwood fibers that retain their cylindrical shape as a result of smaller diameter and thicker walls. Bursting strength and tensile strength of paper tend to increase with increases in the proportion of springwood to summerwood. In contrast, the stiffer summerwood fibers make paper whose resistance to tearing--a highly essential property for kraft paper--increases with the proportion of summerwood fibers.

Fibril Orientation

The orientation of the fibrils in wood fibers has a significant effect on wood quality. Here we are mostly concerned with the angle formed by the cellulosic fibrils in the central layer of the secondary wall with respect to the long axis of fibers (fig. 4). It is evident from microscopy studies that this important layer makes up the bulk of the fiber wall--probably as much as two-thirds of the total wall thickness even in the thin-walled springwood, and far more in the summerwood fibers. The relative bulk of this layer and its largely crystalline cellulosic nature are responsible for the principal pattern, as shown by X-ray diffraction, that serves as a broad indicator of the dominant fibril orientation in the secondary layer.

Fibril angles may vary from 5 degrees or less up to as much as 60 degrees. In springwood fibers they are typically larger than in summerwood. In southern pines, for example, they frequently average 15 to 20 degrees in the springwood, as compared to less than 5 degrees in the summerwood. Even when the fibril angles in the summerwood average as much as 40 to 45 degrees, they are still larger in the springwood, 50 degrees or more.

White ash trees that were seriously deficient in stiffness, static bending, and endwise compressive strength were found to have large fibril angles (9). In another study, a comparison was made of ash grown in creek bottoms and on upland sites. Those grown in the bottoms had significantly larger fibril angles, and wood therefrom tested 30 percent less in modulus of elasticity than the trees from the uplands (11). A study now in progress at the Forest Products Laboratory indicates that an appreciable part of the unexplained variation in endwise stiffness of loblolly pine--not accounted for by specific gravity--may be strongly associated with fibril angle.

Fibril orientation is further tied in with wood quality through its relationship with longitudinal shrinkage. Large fibril angles and excessive longitudinal shrinkage are typical of compression wood, an abnormal kind of wood long associated with serious warp (2), and with normal wood that is inherently prone to warp. On the other hand, small fibril angles--in the 5 to 10 degree range--and low shrinkage along the grain are the rule in typical high density, strong, relatively stable wood.

Fibril orientation also affects pulp yield and quality. In pulping studies of loblolly pine (10), it was found that wood with large fibril angles (20 to 30 degrees) in the summerwood, whether compression wood or normal wood, produced smaller yields of both sulfite and sulfate pulps, per pound of wood in the furnish. These effects were independent of specific gravity and percentage of summerwood. Moreover, pulp from wood with large fibril angles was more difficult to bleach and had much less tearing strength then pulps made from wood that was more nearly average or normal with respect to fibril orientation.

Effects of Growth Rate, Including Nonuniform Growth

Figure 5 shows what happens when low-density, high-shrinkage wood is combined in the same board with more stable wood of higher density. In early life--up to 10 or 12 years of age--many softwoods tend to make excessive diameter increment when grown on good sites relatively free of competition. Wood formed during this period tends to be low in density and high in shrinkage, largely because of low percentage of summerwood and large fibril angles. In softwoods, specific gravity and shrinkage are probably more highly correlated with age from the pith than with growth rate. However this may be, the warping that results from combining such wide-ringed juvenile wood (8) with more mature wood formed later in life is an important cause of degrade in southern pine lumber, and is common in many other second-growth softwoods.

Nonuniform growth is equally undesirable in hardwoods, from the standpoint of dimensional stability as well as machining and finishing characteristics.

More extensive research, systematic mass sampling, better design, and the development of electronic computers capable of determining simultaneously the effects of every possible combination of independent variables, have enabled us in recent years to measure more precisely the effects of various site, tree, and structural characteristics on wood density and other properties. In southern pines, for example, it has been found that growth rate (rings per inch) is only weakly correlated with specific gravity. Of the variables tested, age from the pith has by far the greatest single influence on wood density.

In most of our hardwood species, on the other hand, there is a strong relationship between growth rate and specific gravity. In general, the faster the growth rate, the greater the wood density. Both wide- and narrow-ringed hardwoods are well suited to important, although quite different, uses. Uniformly dense, wide-ringed, second-growth hickory and ash, for example, are preferred for tool handles, athletic equipment, and other products requiring high bending strength and shock resistance. On the other hand, the furniture industry prefers soft-textured wood of moderate, uniform growth because of its lower weight, greater stability, and superior machining and finishing properties.

Within a species, growth rate, usually expressed as rings per inch, seems to be the best single index to machining and finishing properties. The slower the growth rate, the better the machining properties. This relationship, which holds for both ring-porous hardwoods and the softwoods, is largely independent of wood density.

As an extreme example, the vigorous, fast-growing stands of second-growth ponderosa pine near the west coast of the United States are indeed most beautiful to behold. The foresters who manage them are generally bursting with pride. Because of exceptional growth rates, however, the wood produced by these stands is totally unsuitable for and, therefore, largely worthless for, the normally high-value uses--chiefly millwork--that have made ponderosa pine a preferred species. This wide-ringed wood is so poor in machining properties that it is certain to be avoided by millwork plants and other processors long accustomed to a much better quality of ponderosa pine.

Chemical Composition

There has been a great amount of research on the chemical composition of wood. It is generally recognized that the cellulose content is perhaps the most important factor in determining the yield of chemical pulps from a unit weight of wood. In contrast, high lignin content indicates that more substance must be removed in the production of these pulps. Hemicellulose is also recognized as a factor in the strength potential of pulps. Extractives are important in determining the pulping process to be used, give some indication of pulp yield, and may be highly important in predicting natural durability of wood.

Those concerned with developing the potential of wood as a raw material for the production of organic chemicals are interested in the distribution of the various sugars, and such properties as the crystallinity of the cellulose fraction. The latter is important because ease of hydrolysis is correlated with crystalline order.

Unfortunately, most research in this field has been done by chemists who worked with composite wood samples, and who were chiefly interested in differences between species. Accordingly, the results tell us little about individual tree variation in chemical composition, and even less about the source of the variation. Recently, however, Zobel at North Carolina State College (15), Joranson and associates of the Institute of Paper Chemistry (14), and workers at the Forest Products Laboratory, have made chemical analyses of individual trees of some of our more important species. The data indicate that there may be as much variation in chemical makeup as in structural features. This is a fertile field for exploration by geneticists.

Factors That Affect Painting and Gluing Characteristics

Our native softwoods that are used commercially for exterior trim and siding differ widely in their painting characteristics, both within and among species. In this discussion we are more concerned with the wood-quality factors responsible for the observed variations in paint durability than with the well-established differences between species and genera. Extensive tests have shown that commonly used house paints last longest on boards of relatively low density, slow, uniform growth rate (many rings per inch), and that have a small percentage of summerwood in the annual growth ring. Such boards can also be bonded together more readily and more permanently with commonly used adhesives than can wood of higher density, pronounced summerwood bands, and wider growth rings.

Unfortunately, some trade associations continue to promote for use as siding those species and qualities, as here defined, that unquestionably rate at the very bottom of the paintability scale.

Sapwood Thickness

A thick layer of sapwood is preferred or essential for some important uses. For example, many softwoods of the western United States, such as lodgepole pine, are well suited for use as transmission poles and piling except that they tend to have little sapwood. This makes effective treatment with preservatives difficult or impossible, and thus limits the use of these species for poles and piling.

In many of our hardwoods, such as the hard maple, that are widely used for furniture and interior trim as well as veneer, the sapwood is preferred because of its light color, and commands a premium price. An extreme example of consumer preference, as expressed at the market place, is the buyer insistence on light-colored hickory sapwood for tool handles, despite the fact that it has no technical superiority over heartwood for this use.

Effects of Abnormal or Atypical Structure

Historically, compression wood in the softwood species probably excited the earliest interest among workers with wood products, mainly because of its atypical or variant structure, especially of the summerwood parts of the annual rings. Compression wood is characterized by large fibril angles and spiral checking in the middle layer of the secondary walls of the fibers. The large angles, and to some extent the discontinuous wall structure of summerwood, are mainly responsible for excessive longitudinal shrinkage, low stiffness, and highly erratic shock resistance, in addition to the adverse effects on pulp yields and quality already mentioned (10). Figure 6 shows an example of serious warping in prefabricated wall studding caused by the excessive longitudinal shrinkage of compression wood.

In contrast to compression wood, which is formed largely on the under side of leaning softwoods, there is another atypical structural feature, tension wood, which is commonly found on the upper side of leaning hardwoods. In tension wood, a gelatinous type of fiber predominates. These fibers are characteristically low in lignin, have highly crystalline cellulose, and the fibril orientation in the central layer of the secondary wall is essentially parallel. In addition, the gelatinous components behave as if they were loosely attached to the outer layers of the fiber walls.

Tension wood adversely affects wood quality by causing fuzzy surfaces of sawed lumber and of veneer, and torn grain of planed and other machined surfaces, thus making machining and finishing difficult (fig. 7). Longitudinal warp, as bowing, crooking, or twisting of lumber and the buckling of veneer, are commonly associated with tension wood (12). It should be noted that excessive longitudinal shrinkage of tension wood is not associated with large fibril angles in the central layer of the secondary wall, but is probably an effect of the essentially transverse fibril orientation in the outer layers of the fiber walls. Because of the loose attachment between the outer and center layers, the latter seem to have none of the restraint on longitudinal shrinkage that is normally the case with small fibril angles.

Compression Failures

Compression failures (fig. 8), which should not be confused with compression wood, are minute fractures or short, locally deformed areas along the cell walls of fibers. These failures are caused by excessive endwise forces, as during severe windstorms, careless felling, or rough handling of logs and lumber. These localized areas of damaged fibers, each of which extends across at least several annual rings, constitute an important cause of brashness, which permits wood to break suddenly and completely across the grain with the application of relatively small loads (3). The wood of certain trees, because of inherent physical or structural weakness, may be more prone to develop compression failures than others. Failure of many of the broken ladder rails and helicopter rotor blades sent to the Forest Products Laboratory for diagnosis can be attributed to compression failures that in most cases should have been detected by inspection of lumber destined for such uses.

Distinctive Figure

In cabinet hardwoods used chiefly for furniture, interior paneling and trim, decorative veneer, gunstocks, and various specialty and craft items, attractive figure is highly desirable and greatly increases the value. There is no reason why geneticists should not select and breed for distinctive figure in fine hardwoods, including bird's-eye, fiddleback, and the like, and possibly even for the deformities--crotches, burls, and swollen butts--that yield the finest of decorative veneers. The distinctive and highly attractive figure found in the Sherrill hybrid poplar is a fine example of how a normally low-value pulpwood tree can be upgraded into the fancy face-veneer class.

The Need for a Better Concept and Wider Appreciation of Wood Quality

We could spend the remainder of our time discussing additional wood-quality factors, and citing other examples of waste, degrade, and failure in service due largely to ignorance or disregard of basic wood-quality factors. However, we believe you have heard enough today to convince you that there is a lot more to wood quality than size, straightness, and freedom from knots, rot, and other obvious defects with which everyone is familiar.

We think the time has come that the foresters who grow the wood, and the lumbermen and others who process it, must become more familiar with and give more consideration to the basic wood-quality factors that, in the final analysis, determine the suitability of wood for any given use. They need to think of quality in terms that make sense to the principal users of wood, including the technicians who play a key role in determining wood's competitive position at the market place. They are the engineers, architects, furniture designers, and chemists who regard wood simply as another engineering material, compare its chemical, physical, and other properties with those of metals and other competing materials of uniform quality and standardized grades, and specify the material that most nearly meets the requirements of a particular product or end use. In the United States at least, failure to adopt a sound, technically adequate concept of wood quality, and to apply it in the growing, processing, and marketing of wood and wood products, is certain to result in further loss of markets to competing materials.

Evaluation of Wood Quality in Standing Timber

In conclusion, I would like to say just a few words about wood-quality evaluation in standing timber. In recent years the Forest Products Laboratory has worked intensively on developing more efficient methods and equipment for determining the intrinsic quality of wood in living trees from increment core samples. This nondestructive approach to wood-quality evaluation of standing timber has proved extremely valuable in forest resource surveys, in studying the influence of environmental factors or silvicultural treatments on wood quality, and in identifying trees that are unique or superior in some wood-quality feature.

In this country we have enlisted the help of the Forest Survey and their State and industry cooperators. The Forest Survey organization of the U. S. Forest Service is charged with the responsibility of obtaining, and keeping current, basic statistical information on the Nation's forest resources. They have established a Nationwide system of sample plots, randomly located or mechanically placed at the intersection of grids spaced 2 to 4 miles apart. A certain number of these plots are occupied each year, and various measurements made. In certain selected States, now largely in the South, Northeast, and Northwest, increment cores to the pith are taken from all trees sampled. The cores are sent to the Forest Products Laboratory for determination of age, specific gravity, percentage of summerwood, growth rate, fibril angle, and the like. In addition, some are thereafter subjected to chemical analysis and others to micro machining tests.

Since the core samples are taken in connection with the normal work of the Forest Survey, rather than as a special job, the cost per sample is small. We have thus obtained, for the first time in our history, systematically collected, essentially random, wood samples for an entire tree species population over a State, groups of States, or the natural range of the species.

The advantages of such systematic mass sampling on a gigantic scale showed up early in the work. For example, in Mississippi we located a longleaf pine tree with a much higher specific gravity--0.75 at breast height--than any previously recorded. This tree was also above average in growth rate, and acceptable as to form, branching, and other important characteristics. As shown in figure 9, it attained an estimated dry mass of 607 pounds in 34 years, about double the weight of average trees the same age, and almost equal to that of average trees twice its age.

With the wood-quality information now available for Mississippi and certain other southern states, it is possible to present timber resource data in terms of tons (dry weight) of merchantable material available for pulp production classified by species, size class, and on an acre, county, or some other unit-area basis. For the lumberman, good estimates can be made of the proportion of the softwood sawtimber volume--by species, size class, log grade, or area--that will meet minimum commercial specifications for dense and longleaf structural lumber, timbers, and heavy dimension. Similar information is of value to those interested in high-strength piling and transmission poles.

Of equal interest to many of you is the fact that the data from such wood-quality surveys are more adequate than that usually available to wood technologists for study of the effects of site, climate, and other variables on intrinsic wood quality.

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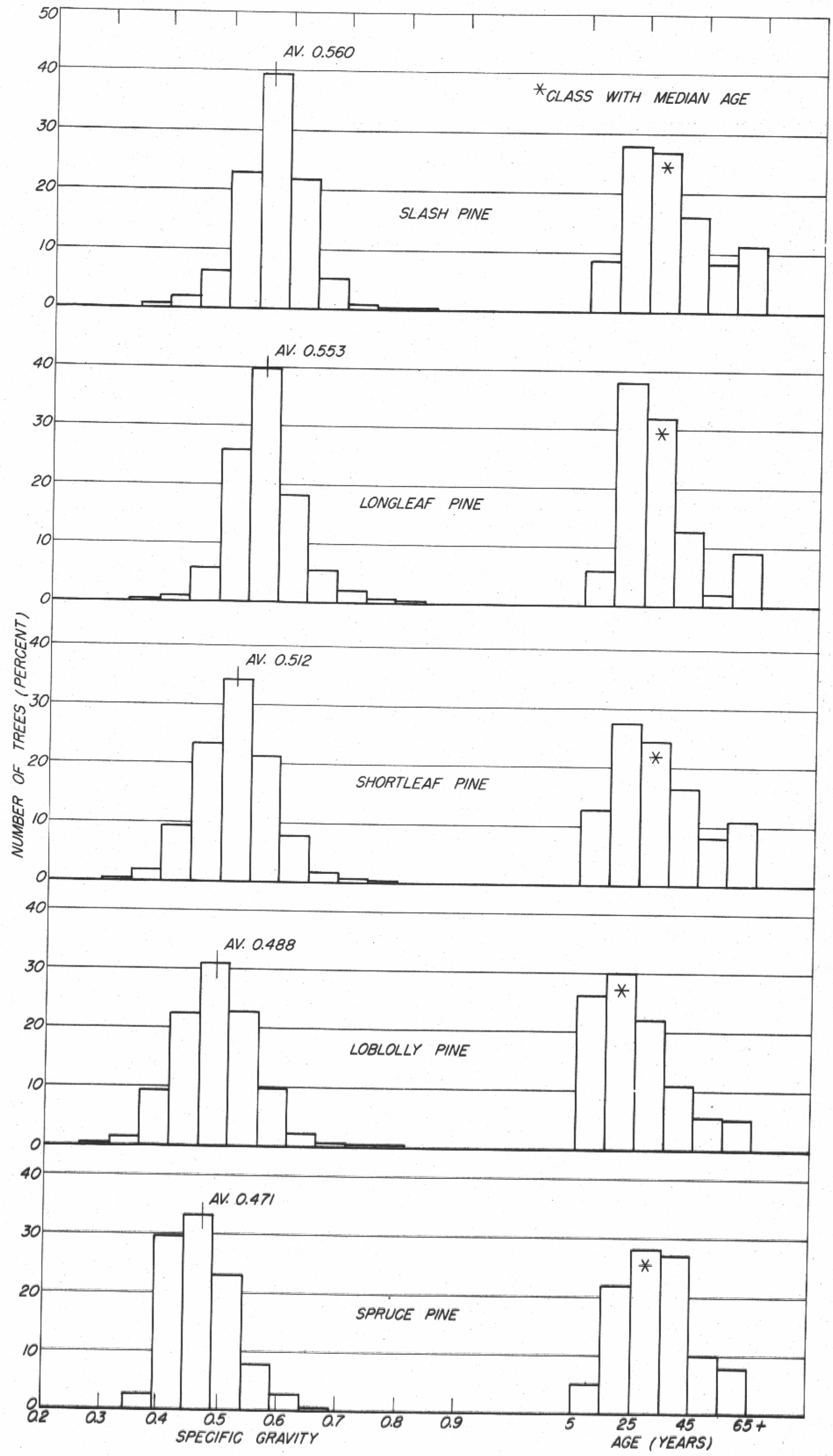

Figure 1. --Frequency distribution of age and core specific gravity at breast height (3 inches d. b. h. and over) for five species of pine in Mississippi. Number of trees in sample: slash, 576; longleaf, 992; shortleaf, 2,815; loblolly, 3,752; spruce pine, 178.

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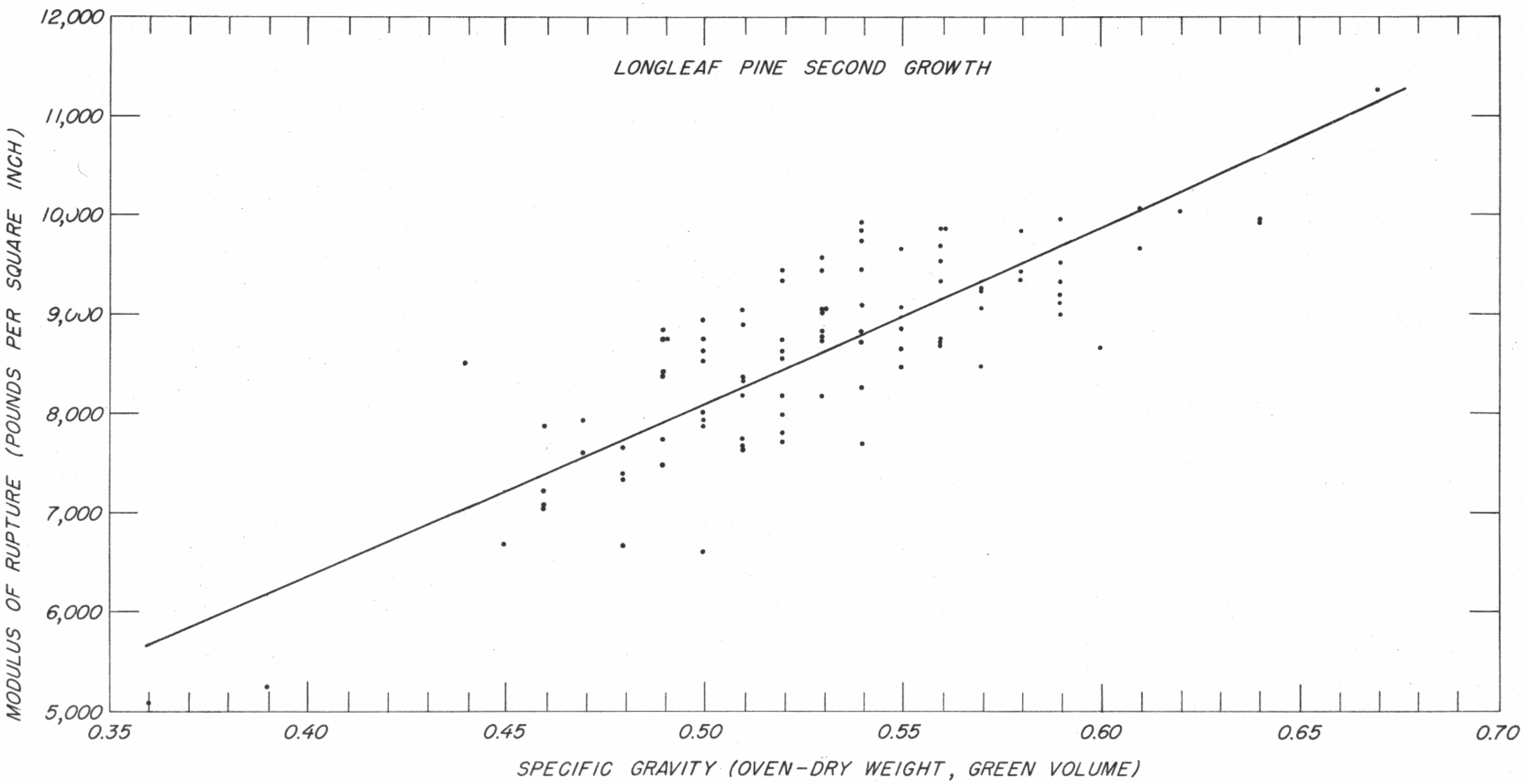

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Figure 2. --Relationship between the specific gravity of longleaf pine wood and its modulus of rupture.

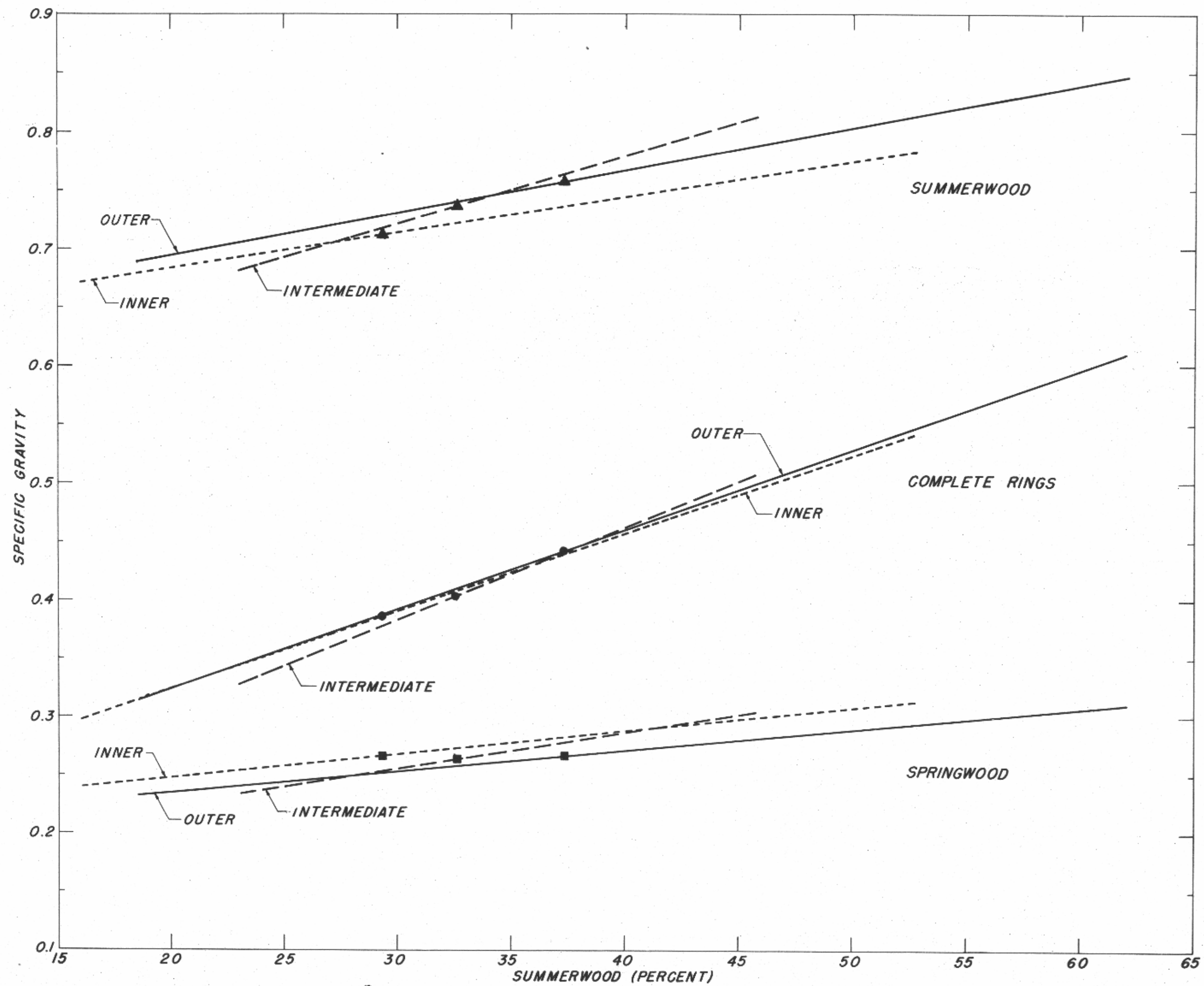

Figure 3. --Regressions of specific gravity on percentage of summerwood for complete annual rings and for the dissected springwood and summerwood of the rings. The length of the regression lines indicates the range in percentage of summerwood for the given zone; the solid points indicate the zone means.

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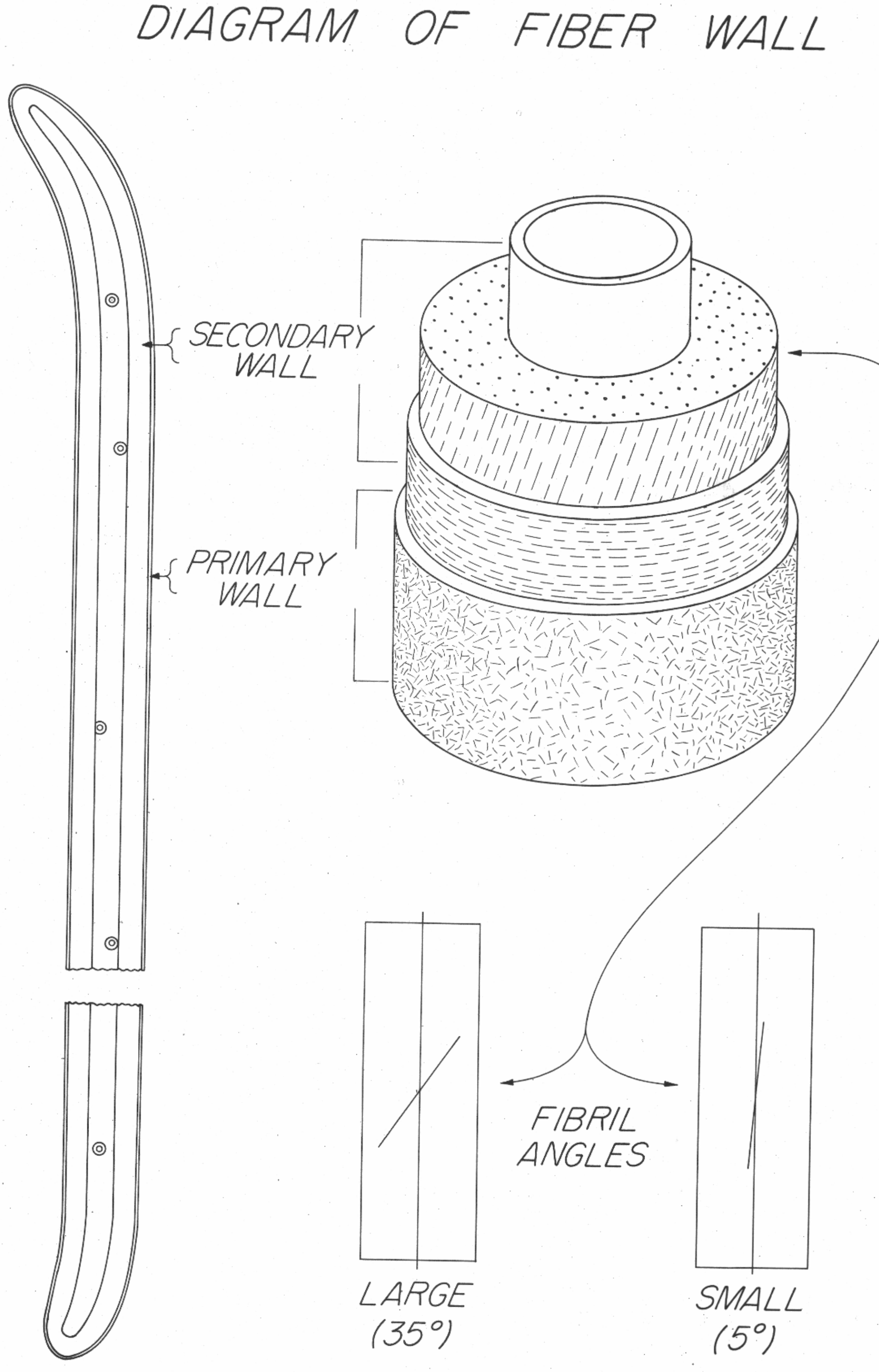

Figure 4. --Schematic diagram of wood fiber showing, upper right, the location of the fibrils in middle layer of the secondary wall, and their orientation with respect to long axis of the fiber.

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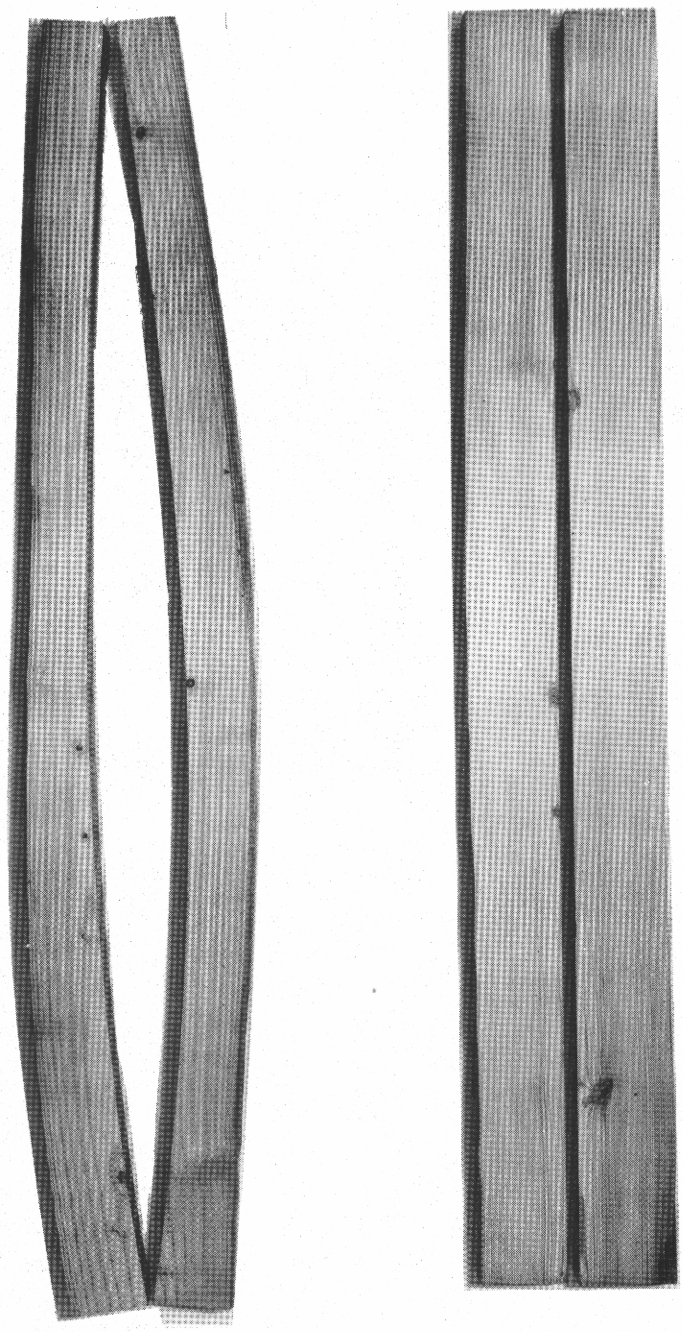

Figure 5.--(Left) Two 2 by 4's ripped from a 2 by 8 sawed approximately through the pith of slash pine which grew very rapidly in the juvenile stage and then at a more moderate rate. Warp is due to greater longitudinal shrinkage of the wide-ringed, low density, juvenile wood, as compared to the older, more stable wood grown at more moderate rate. (Right) Two 2 by 4's from a 2 by 8 sawed approximately through pith of slash pine grown at an even, moderate rate. Here there is little or no stress due to differential shrinkage, hence no warp.

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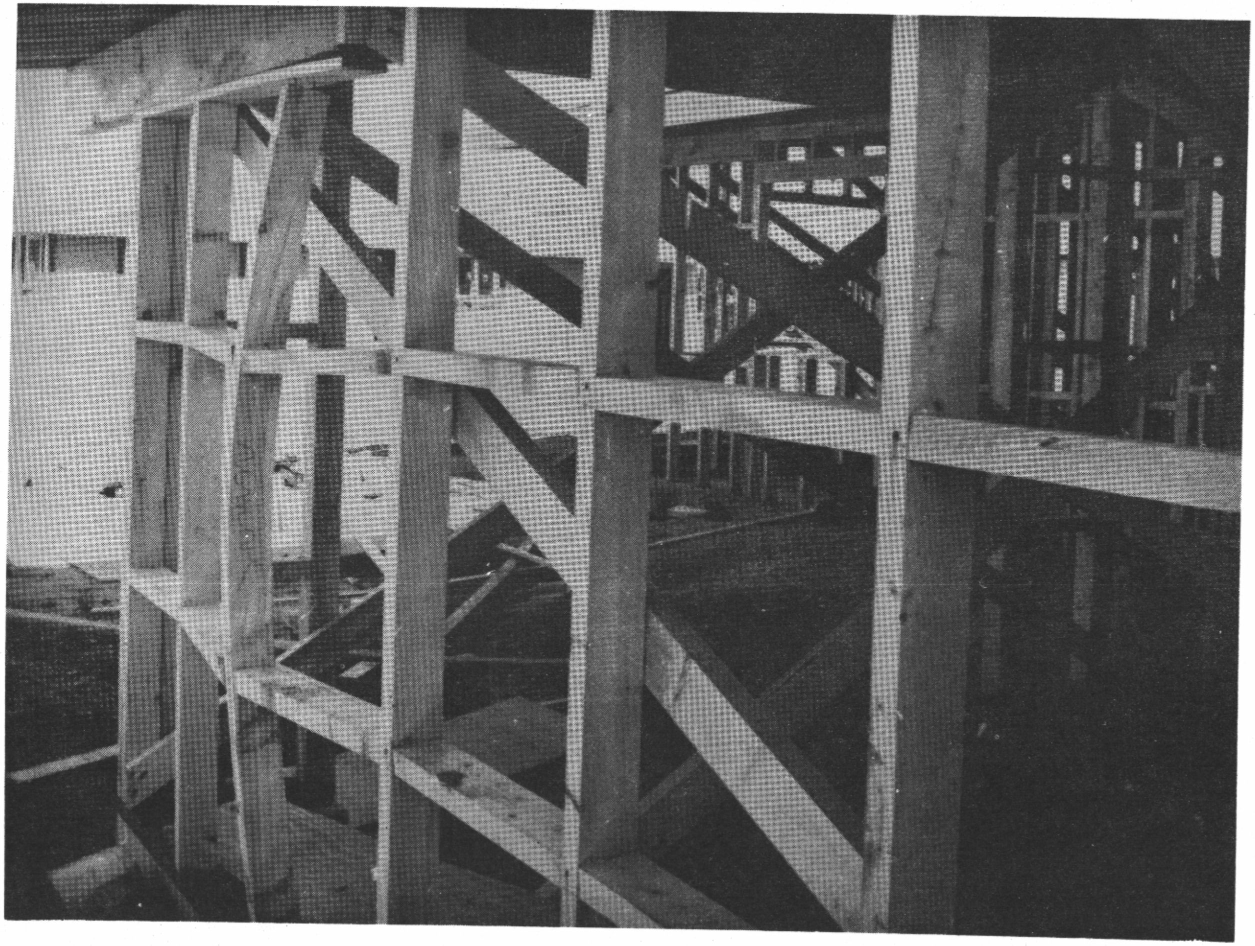

Figure 6. --Crook in stud showing bands of compression wood along the concave edge.

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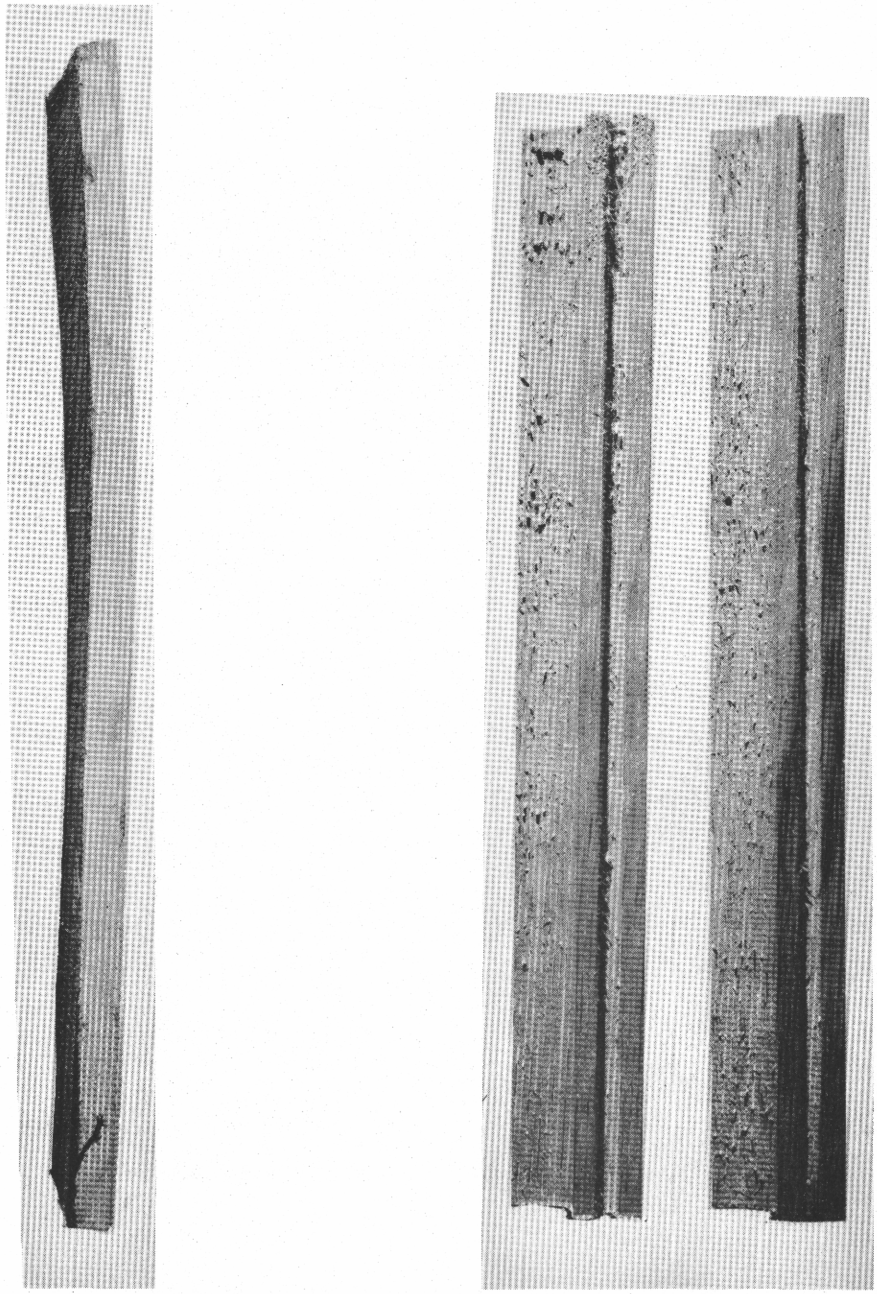

Figure 7. --(Left) Elm board that has warped due to serious tension wood. (Right) Moldings made from cativo showing torn grain and fuzziness in spots containing large number of gelatinous fibers.

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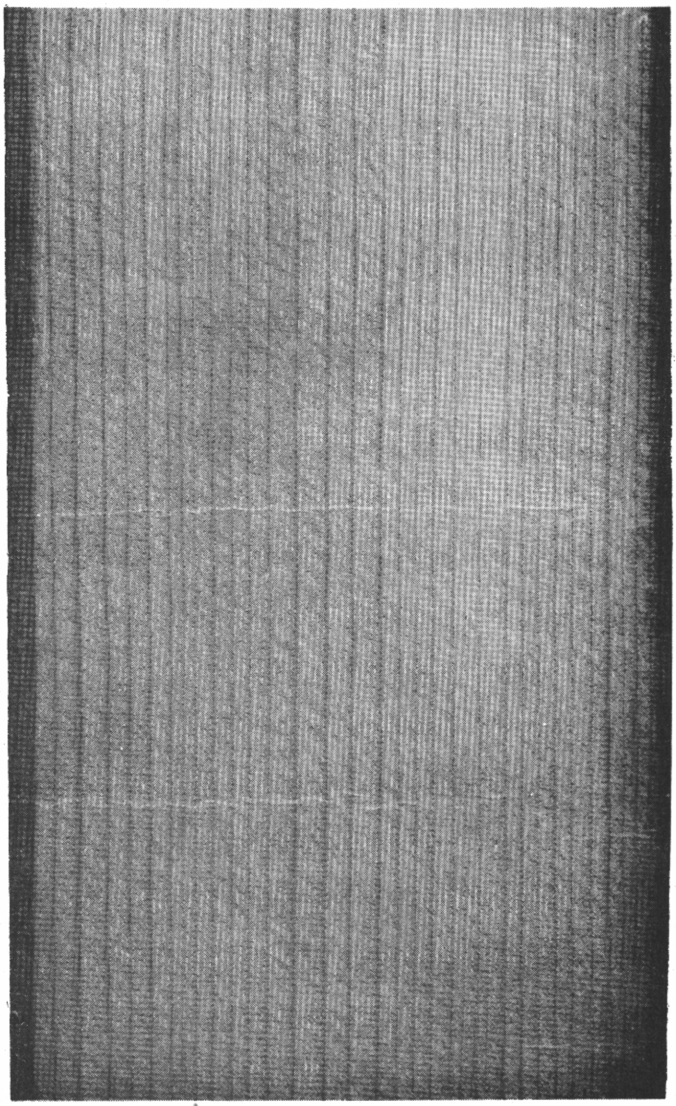

Figure 8. --Clearly visible compression failures found in Sitka spruce ladder rail. If used, this ladder would have broken abruptly, along lines of compression failures, with the application of even relatively light load.

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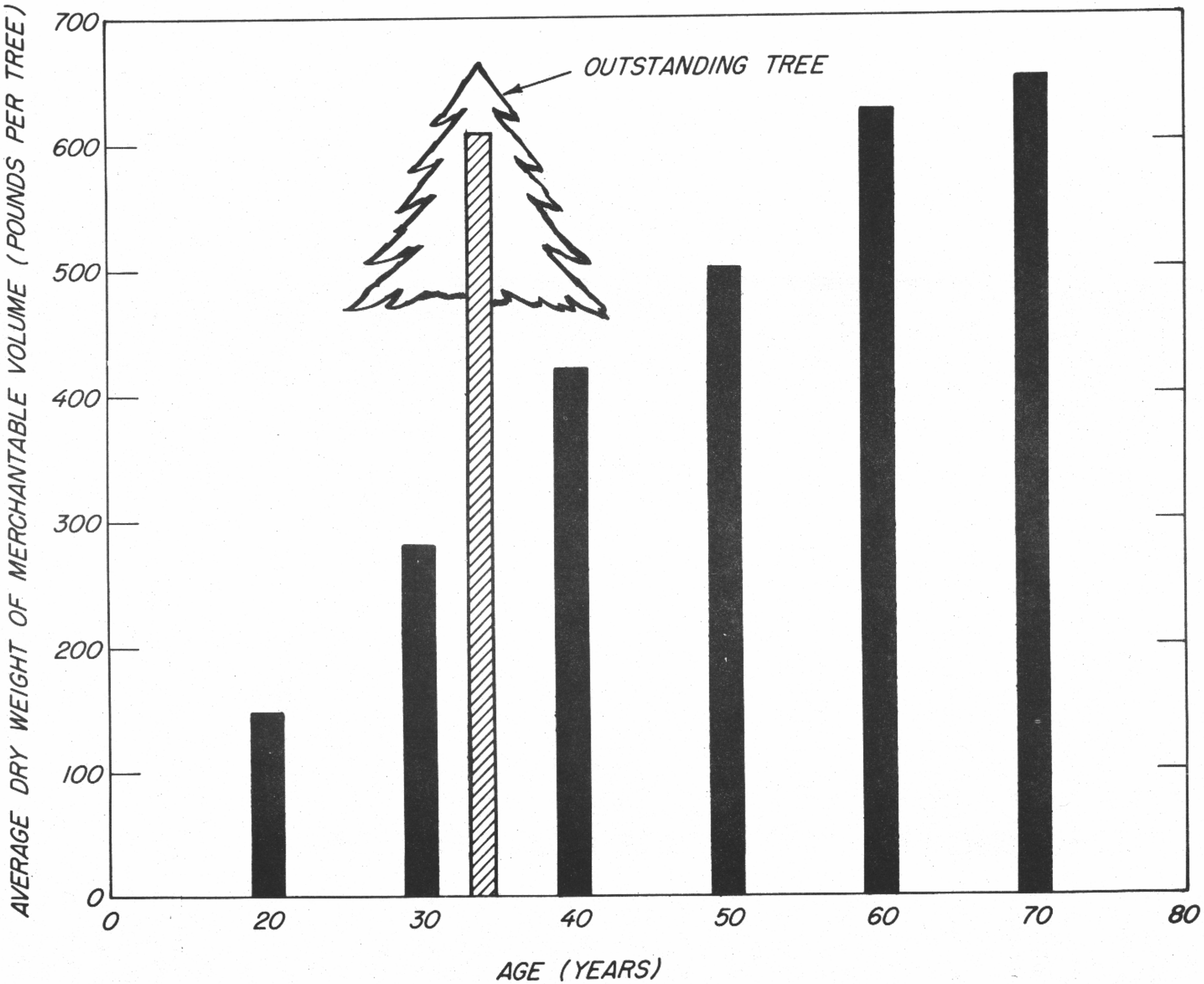

Figure 9. --Merchantable dry weight of outstanding longleaf tree 34 years of age compared with dry weights of average longleaf trees at various ages. Data from the Mississippi Forest Servey.

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SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen
- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.