

WOOD handbook:

Wood as an engineering material

**By
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Summarizes information on wood as an engineering material. Properties of wood and wood-base products of particular concern to the architect and engineer are presented, along with discussions of designing with wood and some pertinent uses of wood.

KEYWORDS: Wood structure, physical properties (wood), mechanical properties (wood), lumber, plywood, panel products, design, fastenings, wood moisture, drying, gluing, fire resistance, finishing, decay, sandwich construction, preservation, and wood-base products.

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PREFACE

Forests, distinct from all their other services and benefits, supply a basic raw material—wood—which from the earliest times has furnished mankind with necessities of existence and with comforts and conveniences beyond number.

One major use has always been in structures, particularly in housing. But despite wood's long service in structures, it has not always been used efficiently. In these days when the Nation is trying to utilize its resources more fully, better and more efficient use of the timber crop is vital.

Authorship

As an aid to more efficient use of wood as a material of construction, this handbook was prepared by the Forest Products Laboratory, a unit of the research organization of the Forest Service, U.S. Department of Agriculture. The Laboratory, established in 1910, is maintained at Madison, Wis., in cooperation with the University of Wisconsin. It was the first institution in the world to conduct general research on wood and its utilization. The vast accumulation of information that has resulted from its engineering and allied investigations of wood and wood products over six decades—along with knowledge of everyday construction practices and problems—is the chief basis for this handbook.

Purpose

This handbook provides engineers, architects, and others with a source of information on the physical and mechanical properties of wood, and how these properties are affected by variations in the wood itself. Practical knowledge of wood has, over the years, resulted in strong and beautiful structures, even though exact engineering data were not always available. Continuing research and evaluation techniques promise to permit wider and more efficient utilization of wood and to encourage even more advanced industrial, structural, and decorative uses.

Organization

Individual chapters describe not only the wood itself, but wood-based products, and the principles of how wood is dried, fastened, finished, and preserved from degradation in today's world. Each chapter is climaxed with a bibliography of allied information. A glossary of terms is presented at the end of the handbook.

The problem of adequately presenting information for the architect, engineer, and builder is complicated by the vast number of tree species he may encounter in wood form. To prevent confusion, the common and botanical names for different species mentioned in this volume conform to the official nomenclature of the Forest Service.

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Chapter 1

CHARACTERISTICS AND AVAILABILITY OF WOODS COMMERCIALLY IMPORTANT TO THE UNITED STATES

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CHARACTERISTICS AND AVAILABILITY OF WOODS COMMERCIALLY IMPORTANT IN THE UNITED STATES

Through the ages the unique characteristics and comparative abundance of wood have made it a natural material for homes and other structures, furniture, tools, vehicles, and decorative objects. Today, for the same reasons, wood is prized for a multitude of uses.

All wood is composed of cellulose, lignin, ash-forming minerals, and extractives formed in a cellular structure. Variations in the characteristics and volume of the four components and differences in cellular structure result in some woods being heavy and some light, some stiff and some flexible, some hard and some soft. For a single species, the properties are relatively constant within limits; therefore, selection of wood by species alone may sometimes be adequate. However, to use wood to its best advantage and most effectively in engineering applications, the effect of specific characteristics or physical properties must be considered.

Historically, some woods have filled many purposes, while others which were not so readily available or so desirable qualitatively might serve only one or two needs. The tough, strong, and durable white oak, for example, was a highly prized wood for shipbuilding, bridges, cooperage, barn timbers, farm implements, railroad crossties, fenceposts, flooring, paneling, and other products. On the other hand, woods such as black walnut and cherry became primarily cabinet woods. Hickory was manufactured into tough, hard resilient striking-tool handles. Black locust was prized for barn timbers and treenails. What the early builder or craftsman learned by trial and error became the basis for the decision as to which species to use for a given purpose, and what characteristics to look for in selecting a tree for a given use. It was commonly accepted that wood from trees grown in certain locations under certain conditions was stronger, more durable, and more easily worked with tools, or finer grained than wood from trees in some other locations. Modern wood quality research has substantiated that location and growth conditions do significantly affect wood properties.

The gradual utilization of the virgin forests in the United States has reduced the available supply of large clear logs for lumber and veneer. However, the importance of high quality logs

has diminished as new concepts of wood use have been introduced. Second-growth timber (fig. 1-1), the balance of the old-growth forests, and imports continue to fill the needs for wood in the quality required. Wood is as valuable an engineering material as it ever was, and in many cases technological advances have made it even more useful.

The inherent factors which keep wood in the forefront of raw materials are many and varied, but one of the chief attributes is its availability in many species, sizes, shapes, and conditions to suit almost every demand. It has a high ratio of strength to weight and a remarkable record for durability and performance as a structural material. Dry wood has good insulating properties against heat, sound, and electricity. It tends to absorb and dissipate vibrations under some conditions of use, yet is an incomparable material for such musical instruments as violins. Because of grain patterns and colors, wood is inherently an esthetically pleasing material, and its appearance may be easily enhanced by stains, varnishes, lacquers, and other finishes. It is easily shaped with tools and fastened with adhesives, nails, screws, bolts, and dowels. When wood is damaged it is easily repaired, and wood structures are easily remodeled or altered. In addition, wood resists oxidation, acid, salt water, and other corrosive agents; has a high salvage value; has good shock resistance; takes treatments with preservatives and fire retardants; and combines with almost any other material for both functional and esthetic uses.

TIMBER RESOURCES AND WOOD USES

In the United States more than 100 woods are available to the prospective user, but it is very unlikely that all are available in any one locality. Commercially, there are about 60 native woods of major importance. Another 30 woods are commonly imported in the form of logs, cants, lumber, and veneer for industrial uses, the building trades, and the craftsman.

A continuing program of timber inventory is in effect in the United States through cooperation of Federal agencies and the States. As new information regarding timber resources becomes available it appears in State and Federal



Figure 1-1.—Reforested area on the Kaniksu National Forest in Idaho. Foreground is stocked with western larch and Douglas-fir reproduced naturally. The central area, edged by mature timber, is a field-planted western white pine plantation. M 513 614

publications. One of the most valuable source books is "Timber Trends in the United States," Forest Service, U.S. Department of Agriculture Forest Resource Report No. 17.

The best source of current information on timber consumption, production, imports, and the demand and price situation is published periodically in a U.S. Department of Agriculture Miscellaneous Publication, entitled "The Demand and Price Situation for Forest Products." Both publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

HARDWOODS AND SOFTWOODS

Trees are divided into two broad classes, usually referred to as "hardwoods" and "softwoods." Some softwoods, however, are actually harder than some of the hardwoods, and some hardwoods are softer than softwoods. For ex-

ample, such softwoods as longleaf pine and Douglas-fir produce wood that is typically harder than the hardwoods basswood and aspen. Botanically, the softwoods are Gymnosperms, species that fall into a classification called conifers that have their seed exposed, usually in cones. Examples are the pines, spruces, redwoods, and junipers. The other broad classification, the Angiosperms, comprise the various orders of hardwoods. They have true flowers and broad leaves, and the seeds are enclosed in a fruit. United States softwoods have needle-like or scalelike leaves that, except for larches and baldcypress, remain on the trees throughout the year. The hardwoods, with a few exceptions, lose their leaves in fall or during the winter. Most of the imported woods, other than those from Canada, are hardwoods.

Major resources of softwood species are spread across the United States, except for the Great Plains where only small areas are for-

ested. Species are often loosely grouped in three general producing areas:

Western softwoods

Douglas-fir	Sitka spruce
Ponderosa pine	Idaho white pine
Western hemlock	Sugar pine
Western redcedar	Lodgepole pine
True firs	Port-Orford-cedar
Redwood	Incense-cedar
Engelmann spruce	Alaska-cedar
Western larch	

Northern softwoods

Eastern white pine
Red pine
Jack pine
Eastern hemlock
Balsam fir
Tamarack
Eastern spruces
Eastern redcedar
Northern white-cedar

Southern softwoods

Southern pine	Eastern redcedar
Baldcypress	Atlantic white-cedar

With some exceptions, most hardwoods occur east of the Great Plains area (fig. 1-2). The following classification is based on the principal producing region for each wood:

Southern hardwoods

Ash	Magnolia
Basswood	Soft maple
American beech	Red oak
Cottonwood	White oak
Elm	Sweetgum
Hackberry	American sycamore
Pecan hickory	Tupelo
True hickory	Black walnut
American holly	Black willow
Black locust	Yellow-poplar

Northern and Appalachian hardwoods

Ash	True hickory
Aspen	Black locust
Basswood	Hard maple
American beech	Soft maple
Birch	Red oak
Black cherry	White oak
American chestnut ¹	American sycamore
Cottonwood	Black walnut
Elm	Yellow-poplar
Hackberry	

Western hardwoods

Red alder	Bigleaf maple
Oregon ash	Paper birch
Aspen	Tanoak
Black cottonwood	

¹ American chestnut is no longer harvested as a living tree, but the lumber is still on the market as "wormy chestnut" and prices are quoted in the Hardwood Market Report.



M 138 574

Figure 1-2.—Mixed northern hardwoods on Ottawa National Forest in Michigan.

COMMERCIAL SOURCES OF WOOD PRODUCTS

Softwoods are available directly from the sawmill, wholesale and retail yards, or lumber brokers. Softwood lumber and plywood are used in construction for forms, scaffolding, framing, sheathing, flooring, ceiling, trim, paneling, cabinets, and many other building components. Softwoods may also appear in the form of shingles, sash, doors, and other millwork, in addition to some rough products such as round treated posts.

Hardwoods are used in construction for flooring, architectural woodwork, trim, and paneling. These items are usually available from lumberyards and building supply dealers. Most hardwood lumber and dimension are re-manufactured into furniture, flooring, pallets, containers, dunnage, and blocking. Hardwood lumber and dimension are available directly from the manufacturer, through wholesalers and brokers, and in some retail yards.

Both softwood and hardwood forest products are distributed throughout the United States, although they tend to be more readily available in or near their area of origin. Local

preferences and the availability of certain species may influence choice; but, a wide selection of woods is generally available for building construction, industrial uses, remanufacturing, and use by home craftsmen.

USE CLASSES AND TRENDS

Some of the many use classifications for wood are growing with the overall national economy, and others are holding about the same levels of production and consumption. The wood-based industries that are growing most vigorously convert wood to thin slices (veneer), particles (chips, flakes, etc.), or fiber pulps and reassemble the elements to produce plywood, numerous types of particleboard, paper, paperboard, and fiberboard products. Another growing wood industry specializes in producing laminated timbers. Annual production by the lumber industry has continued for several years at almost the same board footage. Some of the forest products industries, such as railroad crossties, cooperage, shingles, and shakes appear to have leveled off following a period of depressed production, and in some instances to be making modest increases in production.

COMMERCIAL SPECIES IN THE UNITED STATES

The following brief discussions of the principal localities of occurrence, characteristics, and uses of the main commercial species, or groups of species, will aid in selecting woods for specific purposes. More detailed information on the properties of these and other species is given in various tables throughout this handbook.

Certain uses listed under the individual species are no longer important. They have been included to provide some information on the historical and traditional uses of the species.

The common and botanical names given for the different species conform to the Forest Service official nomenclature for trees.

Hardwoods

Alder, Red

Red alder (*Alnus rubra*) grows along the Pacific coast between Alaska and California. It is used commercially along the coasts of Oregon and Washington and is the most abundant commercial hardwood species in these States.

The wood of red alder varies from almost white to pale pinkish brown and has no visible boundary between heartwood and sapwood. It is moderately light in weight, intermediate in most strength properties, but low in shock resistance. Red alder has relatively low shrinkage.

The principal use of red alder is for furniture, but it is also used for sash, doors, panel stock, and millwork.

Ash

Important species of ash are white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), blue ash (*F. quadrangulata*), black ash (*F. nigra*), pumpkin ash (*F. profunda*), and Oregon ash (*F. latifolia*). The first five of these species grow in the eastern half of the United States. Oregon ash grows along the Pacific coast.

Commercial white ash is a group of species that consists mostly of white ash and green ash, although blue ash is also included. Heartwood of commercial white ash is brown; the sapwood is light colored or nearly white. Second-growth trees have a large proportion of sapwood. Old-growth trees, which characteristically have little sapwood, are scarce.

Second-growth commercial white ash is particularly sought because of the inherent qualities of this wood; it is heavy, strong, hard, stiff, and has high resistance to shock. Because of these qualities such tough ash is used principally for handles, oars, vehicle parts, baseball bats, and other sporting and athletic goods. Some handle specifications call for not less than five or more than 17 growth rings per inch for handles of the best grade. The addition of a weight requirement of 43 or more pounds a cubic foot at 12 percent moisture content will assure excellent material.

Oregon ash has somewhat lower strength properties than white ash, but it is used locally for the same purposes.

Black ash is important commercially in the Lake States. The wood of black ash and pumpkin ash runs considerably lighter in weight than that of commercial white ash. Ash trees growing in southern river bottoms, especially in areas that are frequently flooded for long periods, produce buttresses that contain relatively lightweight and weak wood. Such wood is sometimes separated from tough ash when sold.

Ash wood of lighter weight, including black

ash, is sold as cabinet ash, and is suitable for cooperage, furniture, and shipping containers. Some ash is cut into veneer for furniture, paneling, wire-bound boxes.

Aspen

"Aspen" is a generally recognized name applied to bigtooth aspen (*Populus grandidentata*) and to quaking aspen (*P. tremuloides*). Aspen does not include balsam poplar (*P. balsamifera*) and the species of *Populus* that make up the group of cottonwoods. In lumber statistics of the U.S. Bureau of the Census, however, the term "cottonwood" includes all of the preceding species. Also, the lumber of aspens and cottonwood may be mixed in trade and sold either as poplar ("Popple") or cottonwood. The name "popple" or "poplar" should not be confused with yellow-poplar (*Liriodendron tulipifera*), also known in the trade as "poplar."

Aspen lumber is produced principally in the Northeastern and Lake States. There is some production in the Rocky Mountain States.

The heartwood of aspen is grayish white to light grayish brown. The sapwood is lighter colored and generally merges gradually into heartwood without being clearly marked. Aspen wood is usually straight grained with a fine, uniform texture. It is easily worked. Well-seasoned aspen lumber does not impart odor or flavor to foodstuffs.

The wood of aspen is lightweight and soft. It is low in strength, moderately stiff, moderately low in resistance to shock, and has a moderately high shrinkage.

Aspen is cut for lumber, pallets, boxes and crating, pulpwood, particleboard, excelsior, matches, veneer, and miscellaneous turned articles.

Basswood

American basswood (*Tilia americana*) is the most important of the several native basswood species; next in importance is white basswood (*T. heterophylla*). Other species occur only in very small quantities. Because of the similarity of the wood of the different species, no attempt is made to distinguish between them in lumber form. Other common names of basswood are linden, linn, and beetree.

Basswood grows in the eastern half of the United States from the Canadian provinces southward. Most basswood lumber comes from the Lake, Middle Atlantic, and Central States. In commercial usage, "white basswood" is used to specify white wood or sapwood of either species.

The heartwood of basswood is pale yellowish brown with occasional darker streaks. Basswood has wide, creamy-white or pale brown sapwood that merges gradually into the heartwood. When dry, the wood is without odor or taste. It is soft and light in weight, has fine, even texture, and is straight grained and easy to work with tools. Shrinkage in width and thickness during drying is rated as large; however, basswood seldom warps in use.

Basswood lumber is used mainly in venetian blinds, sash and door frames, molding, apiary supplies, woodenware, and boxes. Some basswood is cut for veneer, cooperage, excelsior, and pulpwood.

Beech, American

Only one species of beech, American beech (*Fagus grandifolia*), is native to the United States. It grows in the eastern one-third of the United States and adjacent Canadian provinces. Greatest production of beech lumber is in the Central and Middle Atlantic States.

Beechwood varies in color from nearly white sapwood to reddish-brown heartwood in some trees. Sometimes there is no clear line of demarcation between heartwood and sapwood. Sapwood may be 3 to 5 inches thick. The wood has little figure and is of close, uniform texture. It has no characteristic taste or odor.

The wood of beech is classed as heavy, hard, strong, high in resistance to shock, and highly adaptable for steam bending. Beech has large shrinkage and requires careful drying. It machines smoothly, is an excellent wood for turning, wears well, and is rather easily treated with preservatives.

Largest amounts of beech go into flooring, furniture, brush blocks, handles, veneer woodenware, containers, cooperage, and laundry appliances. When treated, it is suitable for railway ties.

Birch

The important species of birch are yellow birch (*Betula alleghaniensis*), sweet birch (*B. lenta*), and paper birch (*B. papyrifera*). Other birches of some commercial importance are river birch (*B. nigra*), gray birch (*B. populifolia*), and western paper birch (*B. papyrifera* var. *commutata*).

Yellow birch, sweet birch, and paper birch grow principally in the Northeastern and Lake States. Yellow and sweet birch also grow along the Appalachian Mountains to northern Geo-

rgia. They are the source of most birch lumber and veneer.

Yellow birch has white sapwood and light reddish-brown heartwood. Sweet birch has light-colored sapwood and dark brown heartwood tinged with red. Wood of yellow birch and sweet birch is heavy, hard, strong, and has good shock-resisting ability. The wood is fine and uniform in texture. Paper birch is lower in weight, softer, and lower in strength than yellow and sweet birch. Birch shrinks considerably during drying.

Yellow and sweet birch lumber and veneer go principally into the manufacture of furniture, boxes, baskets, crates, woodenware, cooperage, interior finish, and doors. Birch veneer goes into plywood used for flush doors, furniture, paneling, radio and television cabinets, aircraft, and other specialty uses. Paper birch is used for turned products, including spools, bobbins, small handles, and toys.

Buckeye

Buckeye consists of two species, yellow buckeye (*Aesculus octandra*) and Ohio buckeye (*A. glabra*). They range from the Appalachians of Pennsylvania, Virginia, and North Carolina westward to Kansas, Oklahoma, and Texas. Buckeye is not customarily separated from other species when manufactured into lumber and can be utilized for the same purposes as aspen, basswood, and sap yellow-poplar.

The white sapwood of buckeye merges gradually into the creamy or yellowish white of the heartwood. The wood is uniform in texture, generally straight-grained, light in weight, weak when used as a beam, soft, and low in shock resistance. It is rated low on machineability such as shaping, mortising, steam bending, boring, and turning.

Buckeye is suitable for pulping for paper and in lumber form has been used principally for furniture, boxes, and crates, food containers, woodenware, novelties, and planing mill products.

Butternut

Butternut (*Juglans cinerea*) is also called white walnut, American white walnut, and oilnut. It grows from southern New Brunswick and Maine, west to Minnesota. Its southern range extends into northeastern Arkansas and eastward to western North Carolina.

The narrow sapwood is nearly white, and the heartwood is a light brown, frequently modi-

fied by pinkish tones or darker brown streaks. The wood is moderately light in weight—about the same as eastern white pine—rather coarse-textured, moderately weak in bending and endwise compression, relatively low in stiffness, moderately soft, and moderately high in shock resistance. Butternut machines easily and finishes well. In many ways it resembles black walnut, but it does not have the strength or hardness. Principal uses are for lumber and veneer, which are further manufactured into furniture, cabinets, paneling, trim, and miscellaneous rough items.

Cherry, Black

Black cherry (*Prunus serotina*) is sometimes known as cherry, wild black cherry, wild cherry, or chokecherry. It is the only native species of the genus *Prunus* of commercial importance for lumber production. It occurs scatteringly from southeastern Canada throughout the eastern half of the United States. Production is centered chiefly in the Middle Atlantic States.

The heartwood of black cherry varies from light to dark reddish brown and has a distinctive luster. The sapwood is narrow in old trees and nearly white. The wood has a fairly uniform texture and very satisfactory machining properties. It is moderately heavy. Black cherry is strong, stiff, moderately hard, and has high shock resistance and moderately large shrinkage. After seasoning, it is very dimensionally stable in use.

Black cherry is used principally for furniture, fine veneer panels, architectural woodwork, and for backing blocks on which electrotype plates are mounted. Other uses include burial caskets, woodenware novelties, patterns, and paneling. It has proved satisfactory for gunstocks, but has a limited market for this purpose.

Chestnut, American

American chestnut (*Castanea dentata*) is known also as sweet chestnut. Before chestnut was attacked by a blight, it grew in commercial quantities from New England to northern Georgia. Practically all standing chestnut has been killed by blight, and supplies come from dead timber. There are still quantities of standing dead chestnut in the Appalachian Mountains, which may be available for some time because of the great natural resistance to decay of its heartwood.

The heartwood of chestnut is grayish brown or brown and becomes darker with age. The

sapwood is very narrow and almost white. The wood is coarse in texture, and the growth rings are made conspicuous by several rows of large, distinct pores at the beginning of each year's growth. Chestnut wood is moderately light in weight. It is moderately hard, moderately low in strength, moderately low in resistance to shock, and low in stiffness. It seasons well and is easy to work with tools.

Chestnut was used for poles, railway ties, furniture, caskets, boxes, crates, and core stock for veneer panels. It appears most frequently now as "wormy chestnut" for paneling, trim, and picture frames, while a small amount is still used in rustic fences.

Cottonwood

Cottonwood includes several species of the genus *Populus*. Most important are eastern cottonwood (*P. deltoides* and varieties), also known as Carolina poplar and whitewood; swamp cottonwood (*P. heterophylla*), also known as cottonwood, river cottonwood, and swamp poplar; and black cottonwood (*P. trichocarpa*) and balsam poplar (*P. balsamifera*).

Eastern cottonwood and swamp cottonwood grow throughout the eastern half of the United States. Greatest production of lumber is in the Southern and Central States. Black cottonwood grows in the West Coast States and in western Montana, northern Idaho, and western Nevada. Balsam poplar grows from Alaska across Canada, and in the northern Great Lake states.

The heartwood of the three cottonwoods is grayish white to light brown. The sapwood is whitish and merges gradually with the heartwood. The wood is comparatively uniform in texture, and generally straight grained. It is odorless when well seasoned.

Eastern cottonwood is moderately low in bending and compressive strength, moderately limber, moderately soft, and moderately low in ability to resist shock. Black cottonwood is slightly below eastern cottonwood in most strength properties. Both eastern and black cottonwood have moderately large shrinkage. Some cottonwood is difficult to work with tools because of fuzzy surfaces. Tension wood is largely responsible for this characteristic.

Cottonwood is used principally for lumber, veneer, pulpwood, excelsior, and fuel. The lumber and veneer go largely into boxes, crates, baskets, and pallets.

Elm

Six species of elm grow in the eastern United States: American elm (*Ulmus americana*), slippery elm (*U. rubra*), rock elm (*U. thomasi*), winged elm (*U. alata*), cedar elm (*U. crassifolia*), and September elm (*U. serotina*). American elm is also known as white elm, water elm, and gray elm; slippery elm as red elm; rock elm as cork elm or hickory elm; winged elm as wahoo; cedar elm as red elm or basket elm; and September elm as red elm.

Supply of American elm is threatened by two diseases, Dutch Elm and phloem necrosis, which have killed hundreds of thousands of trees.

The sapwood of the elms is nearly white and the heartwood light brown, often tinged with red. The elms may be divided into two general classes, hard elm and soft elm, based on the weight and strength of the wood. Hard elm includes rock elm, winged elm, cedar elm, and September elm. American elm and slippery elm are the soft elms. Soft elm is moderately heavy, has high shock resistance, and is moderately hard and stiff. Hard elm species are somewhat heavier than soft elm. Elm has excellent bending qualities.

Production of elm lumber is chiefly in the Lake, Central and Southern States.

Elm lumber is used principally in boxes, baskets, crates, and slack barrels; furniture, agricultural supplies and implements; caskets and burial boxes, and vehicles. For some uses the hard elms are preferred. Elm veneer is used for furniture, fruit, vegetable, and cheese boxes, baskets, and decorative panels.

Hackberry

Hackberry (*Celtis occidentalis*) and sugarberry (*C. laevigata*) supply the lumber known in the trade as hackberry. Hackberry grows east of the Great Plains from Alabama, Georgia, Arkansas, and Oklahoma northward, except along the Canadian boundary. Sugarberry overlaps the southern part of the range of hackberry and grows throughout the Southern and South Atlantic States.

The sapwood of both species varies from pale yellow to greenish or grayish yellow. The heartwood is commonly darker. The wood resembles elm in structure.

Hackberry lumber is moderately heavy. It is moderately strong in bending, moderately

weak in compression parallel to the grain, moderately hard to hard, high in shock resistance, but low in stiffness. It has moderately large to large shrinkage but keeps its shape well during seasoning.

Most hackberry is cut into lumber, with small amounts going into dimension stock and some into veneer. Most of it is used for furniture and some for containers.

Hickory, Pecan

Species of the pecan group include bitternut hickory (*Carya cordiformis*), pecan (*C. ilinoensis*), water hickory (*C. aquatica*), and nutmeg hickory (*C. myristicaeformis*). Bitternut hickory grows throughout the eastern half of the United States. Pecan hickory grows from central Texas and Louisiana to Missouri and Indiana. Water hickory grows from Texas to South Carolina. Nutmeg hickory occurs principally in Texas and Louisiana.

The wood of pecan hickory resembles that of true hickory. It has white or nearly white sapwood, which is relatively wide, and somewhat darker heartwood. The wood is heavy and sometimes has very large shrinkage.

Heavy pecan hickory finds use in tool and implement handles and flooring. The lower grades are used in pallets. Many higher grade logs are sliced to provide veneer for furniture and decorative paneling.

Hickory, True

True hickories are found throughout most of the eastern half of the United States. The species most important commercially are shagbark (*Carya ovata*), pignut (*C. glabra*), shellbark (*C. laciniata*), and mockernut (*C. tomentosa*).

The greatest commercial production of the true hickories for all uses is in the Middle Atlantic and Central States. The Southern and South Atlantic States produce nearly half of all hickory lumber.

The sapwood of hickory is white and usually quite thick, except in old, slowly growing trees. The heartwood is reddish. From the standpoint of strength, no distinction should be made between sapwood and heartwood having the same weight.

The wood of true hickory is exceptionally tough, heavy, hard, strong, and shrinks considerably in drying. For some purposes, both rings per inch and weight are limiting factors where strength is important.

The major use for hickory is for tool handles, which require high shock resistance. It is also used for ladder rungs, athletic goods, agricultural implements, dowels, gymnasium apparatus, poles, and furniture.

A considerable quantity of lower grade hickory is not suitable, because of knottiness or other growth features and low density, for the special uses of high-quality hickory. It appears particularly useful for pallets, blocking, and similar items. Hickory sawdust and chips and some solid wood is used by the major packing companies to flavor meat by smoking.

Holly, American

American holly (*Ilex opaca*) is sometimes called white holly, evergreen holly, and boxwood. The natural range of holly extends along the Atlantic coast, gulf coast, and Mississippi Valley.

Both heartwood and sapwood are white, the heartwood with an ivory cast. The wood has a uniform and compact texture; it is moderately low in strength when used as a beam or column and low in stiffness, but it is heavy and hard, and ranks high in shock resistance. It is readily penetrable to liquids and can be satisfactorily dyed. It works well, cuts smoothly, and is used principally for scientific and musical instruments, furniture inlays, and athletic goods.

Honeylocust

The wood of honeylocust (*Gleditsia triacanthos*) possesses many desirable qualities such as attractive figure and color, hardness, and strength, but is little used because of its scarcity. Although the natural range of honeylocust has been extended by planting, it is found most commonly in the eastern United States, except for New England and the South Atlantic and Gulf Coastal Plains.

The sapwood is generally wide and yellowish in contrast to the light red to reddish brown heartwood. It is very heavy, very hard, strong in bending, stiff, resistant to shock, and is durable when in contact with the ground. When available, it is restricted primarily to local uses, such as fence posts and lumber for general construction. Occasionally it will show up with other species in lumber for pallets and crating.

Locust, Black

Black locust (*Robinia pseudoacacia*) is sometimes called yellow locust, white locust, green locust, or post locust. This species grows from Pennsylvania along the Appalachian Mountains to northern Georgia. It is also native to a small area in northwestern Arkansas. The greatest production of black locust timber is in Tennessee, Kentucky, West Virginia, and Virginia.

Locust has narrow, creamy-white sapwood. The heartwood, when freshly cut, varies from greenish yellow to dark brown. Black locust is very heavy, very hard, very high in resistance to shock, and ranks very high in strength and stiffness. It has moderately small shrinkage. The heartwood has high decay resistance.

Black locust is used extensively for round, hewed, or split mine timbers and for fenceposts, poles, railroad ties, stakes, and fuel. An important product manufactured from black locust is insulator pins, a use for which the wood is well adapted because of its strength, decay resistance, and moderate shrinkage and swelling. Other uses are for rough construction, crating, ship treenails and mine equipment.

Magnolia

Three species comprise commercial magnolia—southern magnolia (*Magnolia grandiflora*), sweetbay (*M. virginiana*), and cucumbertree (*M. acuminata*). Other names for southern magnolia are evergreen magnolia, magnolia, big laurel, bull bay, and laurel bay. Sweetbay is sometimes called swamp magnolia, or more often simply magnolia.

The natural range of sweetbay extends along the Atlantic and gulf coasts from Long Island to Texas, and that of southern magnolia from North Carolina to Texas. Cucumbertree grows from the Appalachians to the Ozarks northward to Ohio. Louisiana leads in production of magnolia lumber.

The sapwood of southern magnolia is yellowish white, and the heartwood is light to dark brown with a tinge of yellow or green. The wood, which has close, uniform texture and is generally straight grained, closely resembles yellow-poplar. It is moderately heavy, moderately low in shrinkage, moderately low in bending and compressive strength, moderately hard and stiff, and moderately high in shock resistance. Sweetbay is reported to be much like southern magnolia. The wood of

cucumbertree is similar to that of yellow-poplar, and cucumbertree growing in the yellow-poplar range is not separated from that species on the market.

Magnolia lumber is used principally in the manufacture of furniture, boxes, pallets, venetian blinds, sash, doors, veneer, and millwork.

Maple

Commercial species of maple in the United States include sugar maple (*Acer saccharum*), black maple (*A. nigrum*), silver maple (*A. saccharinum*), red maple (*A. rubrum*), boxelder (*A. negundo*), and bigleaf maple (*A. macrophyllum*). Sugar maple is also known as hard maple, rock maple, sugar tree, and black maple; black maple as hard maple, black sugar maple, and sugar maple; silver maple as white maple, river maple, water maple, and swamp maple; red maple as soft maple, water maple, scarlet maple, white maple, and swamp maple; boxelder as ash-leaved maple, three-leaved maple, and cut-leaved maple; and bigleaf maple as Oregon maple.

Maple lumber comes principally from the Middle Atlantic and Lake States, which together account for about two-thirds of the production.

The wood of sugar maple and black maple is known as hard maple; that of silver maple, red maple, and boxelder as soft maple. The sapwood of the maples is commonly white with a slight reddish-brown tinge. It is from 3 to 5 or more inches thick. Heartwood is usually light reddish brown, but sometimes is considerably darker. Hard maple has a fine, uniform texture. It is heavy, strong, stiff, hard, resistant to shock, and has large shrinkage. Sugar maple is generally straight grained but also occurs as "birdseye," "curley," and "fiddleback" grain. Soft maple is not so heavy as hard maple, but has been substituted for hard maple in the better grades, particularly for furniture.

Maple is used principally for lumber, veneer, crossties, and pulpwood. A large proportion is manufactured into flooring, furniture, boxes, pallets, and crates, shoe lasts, handles, woodenware, novelties, spools, and bobbins.

Oak (Red Oak Group)

Most red oak lumber and other products come from the Southern States, the southern mountain regions, the Atlantic Coastal Plains, and the Central States. The principal species