A BRIEF OVERVIEW of THE PHYSICAL PROPERTIES OF WOODS USED In the MODEL SHIPBUILDING COMMUNITY

by Rex Boocock

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Physical Properties of Wood

Wood is an extremely versatile material. In many cases, more than one property of wood is important to the end product, in this case model ship building. For example, to select a wood species, the value of appearance type properties, such as texture, grain pattern and color may be evaluated against the influence of characteristics such as machineability, dimensional stability, decay resistance and paint adhesion. Wood exchanges moisture with air; the amount and direction of the exchange (gain or loss) depends on the relative humidity, temperature of surrounding air and the current amount of water in the wood. This moisture relationship has an important influence on wood properties and performance.

Grain and texture

The terms grain and texture are commonly used rather loosely in connection with wood. Grain is often used in reference to annual growth rings, but can also indicate the direction of the fibers, as in straight, spiral and curly grain. It can also refer to wood as open and close grained, which are terms reflecting the relative size of the pores. 'Even' texture generally means uniformity in cell dimensions. Fine textured woods have small, even textured cells. Woods that have larger even–sized cells are considered medium textured woods. When the words grain or texture is used, the intended meaning should be made clear.

Plain and Quartersawn

Lumber can be cut from a log in two different ways:

(a) Tangential to the annual rings, producing flatsawn or plainsawn lumber in hardwoods and flatsawn or slash grained lumber in softwoods, and
(b) Radially from the pith or parallel to the rays, producing quartersawn lumber in hardwoods and edge-grained or vertical grained lumber in softwoods (Fig. 3-1)

Quartersawn lumber is not usually cut strictly parallel with the rays. In plainsawn boards, the surfaces next to the edges are often far from tangential to the rings. In practice, lumber with rings at angles of 45° to 90° to the wide surface is called quartersawn, and lumber with angles of 0° to 45° to the wide surface is called plainsawn. Hardwood lumber in which annual rings form angles of 30° to 60° to the wide face is sometimes called bastard sawn. Some advantages of plainsawn and quartersawn lumber are given in Table 3-1

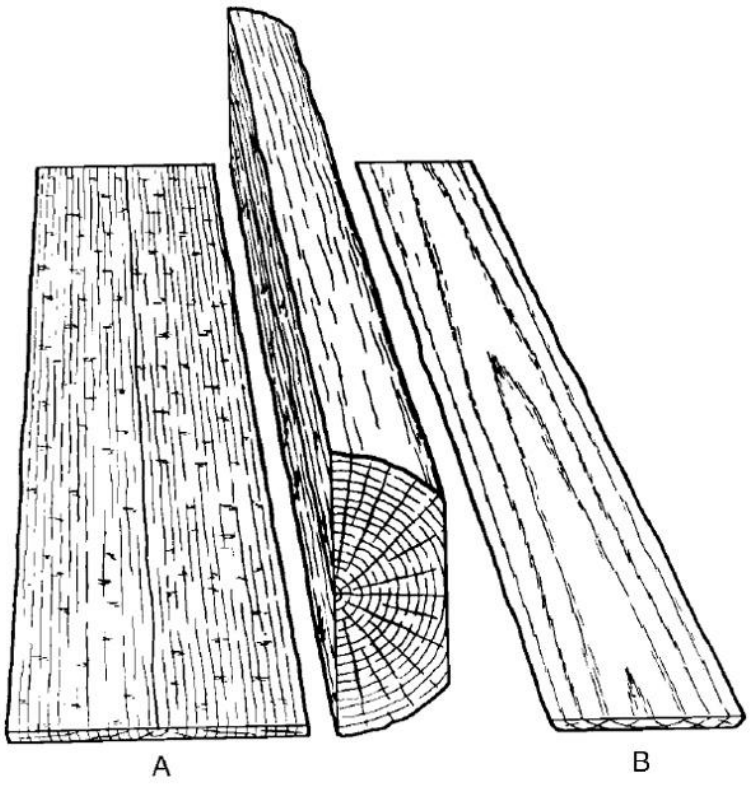

Figure 3–1. Quartersawn (A) and plainsawn (B) boards cut from a log.

Table 3–1. Some advantages of plainsawn and quartersawn lumber

Plainsawn	Quartersawn
Shrinks and swells less in thickness	Shrinks and swells less in width
Surface appearance less affected by round or oval knots compared to effect of spike knots in quartersawn boards; boards with round or oval knots not as weak as boards with spike knots	Cups, surface-checks, and splits less in seasoning and in use
Shakes and pitch pockets, when present, extend through fewer boards	Raised grain caused by separation in annual rings does not become as pronounced
Figure patterns resulting from annual rings and some other types of figure brought out more conspicuously	Figure patterns resulting from pronounced rays, interlocked grain, and wavy grain are brought out more conspicuously
Is less susceptible to collapse in drying	Does not allow liquids to pass through readily in some species
Costs less because it is easy to obtain	Holds paint better in some species
	Sapwood appears in boards at edges and its width is limited by the width of the log

Decorative Features

The decorative value of wood depends upon its color, figure and l s er, as well as the way in which it bleaches or takes fillers, stains, paints and transparent finishes. Because of all the combinations of color and shades, it is impossible to give detailed color descriptions of the various kinds of wood.

Sapwood of most species is light in color, in some species almost white. In most species, heartwood is darker and more uniform in color. In others, such as hemlock, spruce, the true firs, basswood and beech, there is little difference in color between sapwood and heartwood. Table 3-2 describes several common domestic woods.

Table 3–2. Color and figure of several common domestic woods

Species	Color of dry heartwood[a]	Type of figure	
		Plainsawn lumber or rotary-cut veneer	Quartersawn lumber or quarter-sliced veneer
Hardwoods			
Alder, red	Pale pinkish brown	Faint growth ring	Scattered large flakes, sometimes entirely absent
Ash, black	Moderately dark grayish brown	Conspicuous growth ring; occasional burl	Distinct, inconspicuous growth ring stripe; occasional burl
Ash, Oregon	Grayish brown, sometimes with reddish tinge	Conspicuous growth ring; occasional burl	Distinct, inconspicuous growth ring stripe; occasional burl
Ash, white	Grayish brown, sometimes with reddish tinge	Conspicuous growth ring; occasional burl	Distinct, inconspicuous growth ring stripe; occasional burl
Aspen	Light brown	Faint growth ring	None
Basswood	Creamy white to creamy brown, sometimes reddish	Faint growth ring	None
Beech, American	White with reddish to reddish brown tinge	Faint growth ring	Numerous small flakes up to 3.2 mm (1/8 in.) in height
Birch, paper	Light brown	Faint growth ring	None
Birch, sweet	Dark reddish brown	Distinct, inconspicuous growth ring; occasionally wavy	Occasionally wavy
Birch, yellow	Reddish brown	Distinct, inconspicuous growth ring; occasionally wavy	Occasionally wavy
Buttemut, light	Chestnut brown with occasional reddish tinge or streaks	Faint growth ring	None
Cherry, black	Light to dark reddish brown	Faint growth ring; occasional burl	Occasional burl
Chestnut, American	Grayish brown	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Cottonwood	Grayish white to light grayish brown	Faint growth ring	None
Elm, American & rock	Light grayish brown, usually with reddish tinge	Distinct, inconspicuous grown ring with fine wavy pattern	Faint growth ring stripe
Elm, slippery	Dark brown with shades of red	Conspicuous growth ring with fine pattern	Distinct, inconspicuous growth ring stripe
Hackberry	Light yellowish or greenish gray	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Hickory	Reddish brown	Distinct, inconspicuous growth ring	Faint growth ring stripe
Honeylocust	Cherry red	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Locust, black	Golden brown, sometimes with tinge of green	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Magnolia	Light to dark yellowish brown with greenish or purplish tinge	Faint growth ring	None
Maple: black, bigleaf, red, silver, and sugar	Light reddish brown	Faint growth ring, occasionally birds-eye, curly, and wavy	Occasionally curly and wavy
Oaks, all red oaks	Light brown, usually with pink or red tinge	Conspicuous growth ring	Pronounced flake; distinct, inconspicuous growth ring stripe
Oaks, all white oaks	Light to dark brown, rarely with reddish tinge	Conspicuous growth ring	Pronounced flake; distinct, inconspicuous growth ring stripe
Sweetgum	Reddish brown	Faint growth ring; occasional irregular streaks	Distinct, inconspicuous ribbon; occasional streak
Sycamore	Light to dark or reddish brown	Faint growth ring	Numerous pronounced flakes up to 6.4 mm (1/4 in.) in height
Tupelo, black and water	Pale to moderately dark brownish gray	Faint growth ring	Distinct, not pronounced ribbon
Walnut, black	Chocolate brown, occasionally with darker, sometimes purplish streaks	Distinct, inconspicuous growth ring; occasionally wavy, curly, burl, and other types	Distinct, inconspicuous growth ring stripe; occasionally wavy, curly, burl, crotch, and other types
Yellow-poplar	Light to dark yellowish brown with greenish or purplish tinge	Faint growth ring	None

Table 3–2. Color and figure of several common domestic woods—con.

Species	Color of dry heartwood[a]	Type of figure	
		Plainsawn lumber or rotary-cut veneer	Quartersawn lumber or quarter-sliced veneer
Softwoods			
Baldcypress	Light yellowish to reddish brown	Conspicuous irregular growth ring	Distinct, inconspicuous growth ring stripe
Cedar, Atlantic White	Light brown with reddish tinge	Distinct, inconspicuous growth ring	None
Cedar, Eastern red	Brick red to deep reddish brown	Occasionally streaks of white sapwood alternating with heartwood	Occasionally streaks of white sapwood alternating with heartwood
Cedar, incense	Reddish brown	Faint growth ring	Faint growth ring stripe
Cedar, northern White	Light to dark brown	Faint growth ring	Faint growth ring stripe
Cedar, Port-Orford	Light yellow to pale brown	Faint growth ring	None
Cedar, western red	Reddish brown	Distinct, inconspicuous growth ring	Faint growth ring stripe
Cedar, yellow	Yellow	Faint growth ring	None
Douglas-fir	Orange red to red, sometimes yellow	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Fir, balsam	Nearly white	Distinct, inconspicuous growth ring	Faint growth ring stripe
Fir, white	Nearly white to pale reddish brown	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Hemlock, eastern	Light reddish brown	Distinct, inconspicuous growth ring	Faint growth ring stripe
Hemlock, western	Light reddish brown	Distinct, inconspicuous growth ring	Faint growth ring stripe
Larch, western	Russet to reddish brown	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Pine, eastern white	Cream to light reddish brown	Faint growth ring	None
Pine, lodgepole	Light reddish brown	Distinct, inconspicuous growth ring; faint pocked appearance	None
Pine, ponderosa	Orange to reddish brown	Distinct, inconspicuous growth ring	Faint growth ring
Pine, red	Orange to reddish brown	Distinct, inconspicuous growth ring	Faint growth ring
Pine, Southern: longleaf, loblolly, shortleaf, and slash	Orange to reddish brown	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe
Pine, sugar	Light creamy brown	Faint growth ring	None
Pine, western white	Cream to light reddish brown	Faint growth ring	None
Redwood	Cherry red to deep reddish brown	Distinct, inconspicuous growth ring; occasionally wavy and burl	Faint growth ring stripe; occasionally wavy and burl
Spruce: black, Engelmann, red, and white	Nearly white	Faint growth ring	None
Spruce, Sitka	Light reddish brown	Distinct, inconspicuous growth ring	Faint growth ring stripe
Tamarack	Russet brown	Conspicuous growth ring	Distinct, inconspicuous growth ring stripe

[a]Sapwood of all species is light in color or virtually white unless discolored by fungus or chemical stains.

In open grained hardwoods, the appearance of both plainsawn and uartersawn lumber can be varied greatly by the use of fillers of different colors. In softwoods the annual growth layers can be made to stand out by applying a stain. nots, pin wormholes and decay in any lumber should be avoided for model making.

Moisture Content

Moisture content of wood is defined as the weight of water in wood expressed as a fraction, usually percentage, of the weight of kiln dried wood. Weight, shrinkage, strength and all other properties depend upon the moisture content of wood. In trees, the moisture content can range from about 30% to more than 200% of the weight of the wood substance. In softwood, the moisture content of sapwood is usually greater than that of heartwood. In hardwood, the difference between sapwood and heartwood depends more on the species. The average moisture contents are given in Table 3-3. These values are considered typical, but there is considerable variation within and between trees.

Moisture can exist in wood as liquid water (free water) or water vapor in cell lumens and cavities and as water held chemically (bound water) within cell walls. Green wood is often defined as freshly sawn timber in which the cell walls are completely saturated; however, green wood usually contains additional water in the lumen. The moisture content at which both the cell lumens and the cell walls are completely saturated with water is the maximum possible moisture content. The fiber saturation point of wood averages about 30% moisture content, and is often considered as that moisture content below which the physical and mechanical properties begin to change. During drying, the outer parts of a board can be less than fiber saturation while the inner parts are still greater than fiber saturation.

Table 3–3. Average moisture content of green wood, by species

Species	Moisture content[a] (%)	
	Heartwood	Sapwood
Hardwoods		
Alder, red	—	97
Apple	81	74
Ash, black	95	—
Ash, green	—	58
Ash, white	46	44
Aspen	95	113
Basswood, American	81	133
Beech, American	55	72
Birch, paper	89	72
Birch, sweet	75	70
Birch, yellow	74	72
Cherry, black	58	—
Chestnut, American	120	—
Cottonwood	162	146
Elm, American	95	92
Elm, cedar	66	61
Elm, rock	44	57
Hackberry	61	65
Hickory, bitternut	80	54
Hickory, mockernut	70	52
Hickory, pignut	71	49
Hickory, red	69	52
Hickory, sand	68	50
Hickory, water	97	62
Magnolia	80	104
Maple, silver	58	97
Maple, sugar	65	72
Oak, California black	76	75
Oak, northern red	80	69
Oak, southern red	83	75
Oak, water	81	81
Oak, white	64	78
Oak, willow	82	74
Sweetgum	79	137
Sycamore, American	114	130
Tupelo, black	87	115
Tupelo, swamp	101	108
Tupelo, water	150	116
Walnut, black	90	73
Yellow-poplar	83	106
Softwoods		
Baldcypress	121	171
Cedar, eastern red	33	—
Cedar, incense	40	213
Cedar, Port-Orford	50	98
Cedar, western red	58	249
Cedar, yellow	32	166
Douglas-fir, coast type	37	115
Fir, balsam	88	173
Fir, grand	91	136
Fir, noble	34	115
Fir, Pacific silver	55	164
Fir, white	98	160
Hemlock, eastern	97	119
Hemlock, western	85	170
Larch, western	54	119
Pine, loblolly	33	110
Pine, lodgepole	41	120
Pine, longleaf	31	106
Pine, ponderosa	40	148
Pine, red	32	134
Pine, shortleaf	32	122
Pine, sugar	98	219
Pine, western white	62	148
Redwood, old growth	86	210
Spruce, black	52	113
Spruce, Engelmann	51	173
Spruce, Sitka	41	142
Tamarack	49	—

[a]Based on weight when ovendry.

Equilibrium Moisture Content

The moisture content of wood below the fibre saturation point is a function of both relative humidity and temperature of the surrounding air. Equilibrium Moisture Content (EMC) is defined as that moisture content at which the wood neither gaining nor losing moisture: an equilibrium condition has been reached. The relationship between EMC, relative humidity and temperature is shown in Table 3-4. For most practical purposes, the values may be applied to wood of any species.

Table 3–4. Moisture content of wood in equilibrium with stated temperature and relative humidity

Temperature		Moisture content (%) at various relative humidity values																	
(°C	(°F))	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
–1.1	(30)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
4.4	(40)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3
10.0	(50)	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
15.6	(60)	1.3	2.5	3.6	4.6	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1
21.1	(70)	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
26.7	(80)	1.3	2.4	3.5	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6
32.2	(90)	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
37.8	(100)	1.2	2.3	3.3	4.2	5.0	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9
43.3	(110)	1.1	2.2	3.2	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4
48.9	(120)	1.1	2.1	3.0	3.9	4.7	5.4	6.1	6.8	7.5	8.2	8.9	9.7	10.6	11.7	12.9	14.4	16.2	18.6	22.0
54.4	(130)	1.0	2.0	2.9	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5
60.0	(140)	0.9	1.9	2.8	3.6	4.3	5.0	5.7	6.3	7.0	7.7	8.4	9.1	10.0	11.0	12.1	13.6	15.3	17.7	21.0
65.6	(150)	0.9	1.8	2.6	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4
71.1	(160)	0.8	1.6	2.4	3.2	3.9	4.6	5.2	5.8	6.4	7.1	7.8	8.5	9.3	10.3	11.4	12.7	14.4	16.7	19.9
76.7	(170)	0.7	1.5	2.3	3.0	3.7	4.3	4.9	5.6	6.2	6.8	7.4	8.2	9.0	9.9	11.0	12.3	14.0	16.2	19.3
82.2	(180)	0.7	1.4	2.1	2.8	3.5	4.1	4.7	5.3	5.9	6.5	7.1	7.8	8.6	9.5	10.5	11.8	13.5	15.7	18.7
87.8	(190)	0.6	1.3	1.9	2.6	3.2	3.8	4.4	5.0	5.5	6.1	6.8	7.5	8.2	9.1	10.1	11.4	13.0	15.1	18.1
93.3	(200)	0.5	1.1	1.7	2.4	3.0	3.5	4.1	4.6	5.2	5.8	6.4	7.1	7.8	8.7	9.7	10.9	12.5	14.6	17.5
98.9	(210)	0.5	1.0	1.6	2.1	2.7	3.2	3.8	4.3	4.9	5.4	6.0	6.7	7.4	8.3	9.2	10.4	12.0	14.0	16.9
104.4	(220)	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.5	5.0	5.6	6.3	7.0	7.8	8.8	9.9			
110.0	(230)	0.3	0.8	1.2	1.6	2.1	2.6	3.1	3.6	4.2	4.7	5.3	6.0	6.7						
115.6	(240)	0.3	0.6	0.9	1.3	1.7	2.1	2.6	3.1	3.5	4.1	4.6								
121.1	(250)	0.2	0.4	0.7	1.0	1.3	1.7	2.1	2.5	2.9										
126.7	(260)	0.2	0.3	0.5	0.7	0.9	1.1	1.4												
132.2	(270)	0.1	0.1	0.2	0.3	0.4	0.4													

Sorbtion Hysteresis

The amount of water adsorbed from a dry condition to equilibrium with any relative humidity is always less than the amount retained in the process of drying from a wetter condition to equilibrium with that same relative humidity.

The ratio of adsorption EMC to desorption EMC is constant at about 0.85. Data in Figure 3-2 is thought to represent a condition midway between adsorption and desorption.

Shrinkage

Wood is dimensionally stable when the moisture content is greater than the fibre saturation point. Wood changes dimension as it gains or loses moisture below that point. It shrinks when losing moisture from the cell walls and swells when gaining it. This shrinking and swelling can result in warping, checking, splitting, and loosening. It is therefore important that these phenomena be understood for model making.

Wood is an anisotropic material, it shrinks most in the direction of the annual growth rings (tangentially), about half as much across the grain (radially), and only slightly along the grain (longitudinally). The combined effects can distort the shape of wood pieces. The major types of distortion as a result of these effects are illustrated in Fig 3-3 ble s o s s ri e l es of so e o es ic oo s ble s o s s ri e l es of so e i or e oo s

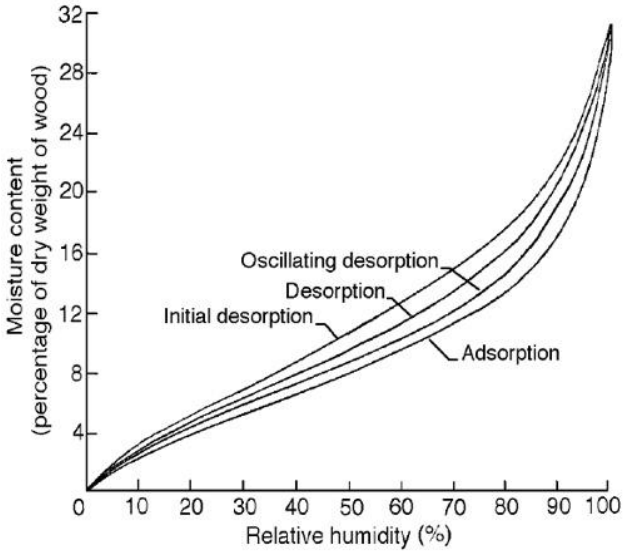

Figure 3–2. Moisture content–relative humidity relationship for wood under adsorption and various desorption conditions.

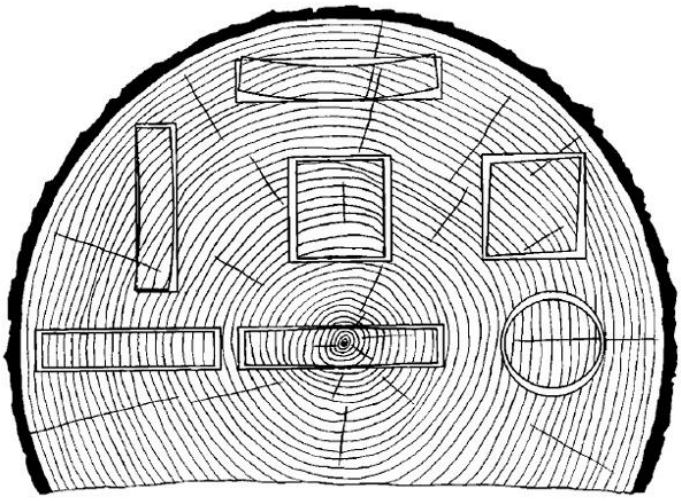

Figure 3–3. Characteristic shrinkage and distortion of flat, square, and round pieces as affected by direction of growth rings. Tangential shrinkage is about twice as great as radial.

Table 3–5. Shrinkage values of domestic woods

Species	Shrinkage[a] (%) from green to ovendry moisture content		
	Radial	Tangential	Volumetric
Hardwoods			
Alder, red	4.4	7.3	12.6
Ash			
Black	5.0	7.8	15.2
Blue	3.9	6.5	11.7
Green	4.6	7.1	12.5
Oregon	4.1	8.1	13.2
Pumpkin	3.7	6.3	12.0
White	4.9	7.8	13.3
Aspen			
Bigtooth	3.3	7.9	11.8
Quaking	3.5	6.7	11.5
Basswood, American	6.6	9.3	15.8
Beech, American	5.5	11.9	17.2
Birch			
Alaska paper	6.5	9.9	16.7
Gray	5.2	—	14.7
Paper	6.3	8.6	16.2
River	4.7	9.2	13.5
Sweet	6.5	9.0	15.6
Yellow	7.3	9.5	16.8
Buckeye, yellow	3.6	8.1	12.5
Butternut	3.4	6.4	10.6
Cherry, black	3.7	7.1	11.5
Chestnut, American	3.4	6.7	11.6
Cottonwood			
Balsam poplar	3.0	7.1	10.5
Black	3.6	8.6	12.4
Eastern	3.9	9.2	13.9
Elm			
American	4.2	9.5	14.6
Cedar	4.7	10.2	15.4
Rock	4.8	8.1	14.9
Slippery	4.9	8.9	13.8
Winged	5.3	11.6	17.7
Hackberry	4.8	8.9	13.8
Hickory, pecan	4.9	8.9	13.6
Hickory, true			
Mockernut	7.7	11.0	17.8
Pignut	7.2	11.5	17.9
Shagbark	7.0	10.5	16.7
Shellbark	7.6	12.6	19.2
Holly, American	4.8	9.9	16.9
Honeylocust	4.2	6.6	10.8
Locust, black	4.6	7.2	10.2
Madrone, Pacific	5.6	12.4	18.1
Magnolia			
Cucumbertree	5.2	8.8	13.6
Southern	5.4	6.6	12.3
Sweetbay	4.7	8.3	12.9
Maple			
Bigleaf	3.7	7.1	11.6
Black	4.8	9.3	14.0
Red	4.0	8.2	12.6
Silver	3.0	7.2	12.0
Striped	3.2	8.6	12.3
Sugar	4.8	9.9	14.7
Oak, red			
Black	4.4	11.1	15.1
Laurel	4.0	9.9	19.0
Northern red	4.0	8.6	13.7
Pin	4.3	9.5	14.5
Scarlet	4.4	10.8	14.7
Southern red	4.7	11.3	16.1
Water	4.4	9.8	16.1
Willow	5.0	9.6	18.9
Oak, white	4.4	8.8	12.7
Bur	5.3	10.8	16.4
Oak, white—con.			
Chestnut			
Live	6.6	9.5	14.7
Overcup	5.3	12.7	16.0
Post	5.4	9.8	16.2
Swamp, chestnut	5.2	10.8	16.4
White	5.6	10.5	16.3
Persimmon, common	7.9	11.2	19.1
Sassafras	4.0	6.2	10.3
Sweetgum	5.3	10.2	15.8
Sycamore, American	5.0	8.4	14.1
Tanoak	4.9	11.7	17.3
Tupelo			
Black	5.1	8.7	14.4
Water	4.2	7.6	12.5
Walnut, black	5.5	7.8	12.8
Willow, black	3.3	8.7	13.9
Yellow-poplar	4.6	8.2	12.7
Softwoods			
Cedar			
Yellow	2.8	6.0	9.2
Atlantic white	2.9	5.4	8.8
Eastern redcedar	3.1	4.7	7.8
Incense	3.3	5.2	7.7
Northern white	2.2	4.9	7.2
Port-Orford	4.6	6.9	10.1
Western redcedar	2.4	5.0	6.8
Douglas-fir,			
Coast[b]	4.8	7.6	12.4
Interior north[b]	3.8	6.9	10.7
Interior west[b]	4.8	7.5	11.8
Fir			
Balsam	2.9	6.9	11.2
California red	4.5	7.9	11.4
Grand	3.4	7.5	11.0
Noble	4.3	8.3	12.4
Pacific silver	4.4	9.2	13.0
Subalpine	2.6	7.4	9.4
White	3.3	7.0	9.8
Hemlock			
Eastern	3.0	6.8	9.7
Mountain	4.4	7.1	11.1
Western	4.2	7.8	12.4
Larch, western	4.5	9.1	14.0
Pine			
Eastern white	2.1	6.1	8.2
Jack	3.7	6.6	10.3
Loblolly	4.8	7.4	12.3
Lodgepole	4.3	6.7	11.1
Longleaf	5.1	7.5	12.2
Pitch	4.0	7.1	10.9
Pond	5.1	7.1	11.2
Ponderosa	3.9	6.2	9.7
Red	3.8	7.2	11.3
Shortleaf	4.6	7.7	12.3
Slash	5.4	7.6	12.1
Sugar	2.9	5.6	7.9
Virginia	4.2	7.2	11.9
Western white	4.1	7.4	11.8
Redwood			
Old growth	2.6	4.4	6.8
Young growth	2.2	4.9	7.0
Spruce			
Black	4.1	6.8	11.3
Engelmann	3.8	7.1	11.0
Red	3.8	7.8	11.8
Sitka	4.3	7.5	11.5
Tamarack	3.7	7.4	13.6

[a]Expressed as a percentage of the green dimension.
[b]Coast type Douglas-fir is defined as Douglas-fir growing in the States of Oregon and Washington west of the summit of the Cascade Mountains. Interior West includes the State of California and all counties in Oregon and Washington east of but adjacent to the Cascade summit. Interior North includes the remainder of Oregon and Washington and the States of Idaho, Montana, and Wyoming.

Table 3–6. Shrinkage for some woods imported into the United States[a]

Species	Shrinkage[b] from green to ovendry moisture content (%)			Location[c]
	Radial	Tangential	Volumetric	
Afrormosia (*Pericopsis elata*)	3.0	6.4	10.7	AF
Albarco (*Cariniana* spp.)	2.8	5.4	9.0	AM
Andiroba (*Carapa guianensis*)	3.1	7.6	10.4	AM
Angelin (*Andira inermis*)	4.6	9.8	12.5	AM
Angelique (*Dicorynia guianensis*)	5.2	8.8	14.0	AM
Apitong (*Dipterocarpus* spp.)	5.2	10.9	16.1	AS
Avodire (*Turreanthus africanus*)	4.6	6.7	12.0	AF
Azobe (*Lophira alata*)	8.4	11.0	17.0	AM
Balata (*Manilkara bidentata*)	6.3	9.4	16.9	AM
Balsa (*Ochroma pyramidale*)	3.0	7.6	10.8	AM
Banak (*Virola* spp.)	4.6	8.8	13.7	AM
Benge (*Guibourtia arnoldiana*)	5.2	8.6	13.8	AF
Bubinga (*Guibourtia* spp.)	5.8	8.4	14.2	AF
Bulletwood (*Manilkara bidentata*)	6.3	9.4	16.9	AM
Caribbean pine (*Pinus caribaea*)	6.3	7.8	12.9	AM
Cativo (*Prioria copaifera*)	2.4	5.3	8.9	AM
Ceiba (*Ceiba pentandra*)	2.1	4.1	10.4	AM
Cocobolo (*Dalbergia retusa*)	2.7	4.3	7.0	AM
Courbaril (*Hymenaea courbaril*)	4.5	8.5	12.7	AM
Cuangare (*Dialyanthera* spp.)	4.2	9.4	12.0	AM
Degame (*Calycophyllum cand idissimum*)	4.8	8.6	13.2	AM
Determa (*Ocotea rubra*)	3.7	7.6	10.4	AM
Ebony, East Indian (*Diospyros* spp.)	5.4	8.8	14.2	AS
Ebony, African (*Diospyros* spp.)	9.2	10.8	20.0	AF
Ekop (*Tetraberlinia tubmaniana*)	5.6	10.2	15.8	AF
Gmelina (*Gmelina arborea*)	2.4	4.9	8.8	AS
Goncalo alves (*Astronium graveolens*)	4.0	7.6	10.0	AM
Greenheart (*Ocotea rodiaei*)	8.8	9.6	17.1	AM
Hura (*Hura crepitans*)	2.7	4.5	7.3	AM
Ilomba (*Pycnanthus angolensis*)	4.6	8.4	12.8	AF
Imbuia (*Phoebe porosa*)	2.7	6.0	9.0	AM
Ipe (*Tabebuia* spp.)	6.6	8.0	13.2	AM
Iroko (*Chlorophora excelsa* and *C. regia*)	2.8	3.8	8.8	AF
Jarrah (*Eucalyptus marginata*)	7.7	11.0	18.7	AS
Jelutong (*Dyera costulata*)	2.3	5.5	7.8	AS
Kaneelhart (*Licaria* spp.)	5.4	7.9	12.5	AM
Kapur (*Dryobalanops* spp.)	4.6	10.2	14.8	AS
Karri (*Eucalyptus diversicolor*)	7.8	12.4	20.2	AS
Kempas (*Koompassia malaccensis*)	6.0	7.4	14.5	AS
Keruing (*Dipterocarpus* spp.)	5.2	10.9	16.1	AS
Lauan, light red and red (*Shorea* spp.)	4.6	8.5	14.3	AS
Lauan, dark red (*Shorea* spp.)	3.8	7.9	13.1	AS
Lauan, white (*Pentacme contorta*)	4.0	7.7	11.7	AS
Limba (*Terminalia superba*)	4.5	6.2	10.8	AF
Macawood (*Platymiscium* spp.)	2.7	3.5	6.5	AM
Mahogany, African (*Khaya* spp.)	2.5	4.5	8.8	AF
Mahogany, true (*Swietenia macrophylla*)	3.0	4.1	7.8	AM
Manbarklak (*Eschweilera* spp.)	5.8	10.3	15.9	AM
Manni (*Symphonia globulifera*)	5.7	9.7	15.6	AM
Marishballi (*Licania* spp.)	7.5	11.7	17.2	AM
Meranti, white (*Shorea* spp.)	3.0	6.6	7.7	AS
Meranti, yellow (*Shorea* spp.)	3.4	8.0	10.4	AS
Merbau (*Intsia bijuga* and *I. palembanica*)	2.7	4.6	7.8	AS
Mersawa (*Anisoptera* spp.)	4.0	9.0	14.6	AS
Mora (*Mora* spp.)	6.9	9.8	18.8	AM
Obeche (*Triplochiton scleroxylon*)	3.0	5.4	9.2	AF
Ocota pine (*Pinus oocarpa*)	4.6	7.5	12.3	AM
Okoume (*Aucoumea klaineana*)	4.1	6.1	11.3	AF
Opepe (*Nauclea* spp.)	4.5	8.4	12.6	AF
Ovangkol (*Guibourta ehie)*	4.5	8.2	12	AF
Para-angelium (*Hymenolobium excelsum*)	4.4	7.1	10.2	AM
Parana pine (*Araucaria angustifolia*)	4.0	7.9	11.6	AS
Pau Marfim (*Balfourodendron riedelianum*)	4.6	8.8	13.4	AM
Peroba de campos (*Paratecoma peroba*)	3.8	6.6	10.5	AM
Peroba Rosa (*Aspidosperma* spp.)	3.8	6.4	11.6	AM
Piquia (*Caryocar* spp.)	5.0	8.0	13.0	AM
Pilon (*Hyeronima* spp.)	5.4	11.7	17.0	AM
Primavera (*Cybistax donnell-smithii*)	3.1	5.1	9.1	AM
Purpleheart (*Peltogyne* spp.)	3.2	6.1	9.9	AM
Ramin (*Gonystylus* spp.)	4.3	8.7	13.4	AS
Roble (*Quercus* spp.)	6.4	11.7	18.5	AM
Roble (*Tabebuia* spp. Roble group)	3.6	6.1	9.5	AM
Rosewood, Brazilian (*Dalbergia nigra*)	2.9	4.6	8.5	AM
Rosewood, Indian (*Dalbergia latifolia*)	2.7	5.8	8.5	AS
Rubberwood (*Hevea brasiliensis*)	2.3	5.1	7.4	AM
Sande (*Brosimum* spp. Utile group)	4.6	8.0	13.6	AM
Sapele (*Entandrophragma cylindricum*)	4.6	7.4	14.0	AF
Sepetir (*Pseudosindora* spp. and *Sindora* spp.)	3.7	7.0	10.5	AS
Spanish-cedar (*Cedrela* spp.)	4.2	6.3	10.3	AM
Sucupira (*Diplotropis purpurea*)	4.6	7.0	11.8	AM
Teak (*Tectona grandis*)	2.5	5.8	7.0	AS
Wallaba (*Eperua* spp.)	3.6	6.9	10.0	AM

[a]Shrinkage values were obtained from world literature and may not represent a true species average.
[b]Expressed as a percentage of the green dimension.
[c]AF is Africa; AM is Tropical America; AS is Asia and Oceania.

Working Qualities

The ease of working wood with hand tools generally varies directly with the specific gravity of the wood. The lower the specific gravity, the easier it is to cut the wood with sharp tools. Tables 3-7 and 3-7A list the specific gravity values for various native and imported species, and can be used as a general guide to the ease of working with hand tools.

Table 3-7 Hardwood – Specific Gravity

Species	Specific gravity
Hardwoods	
Ash	
Black	0.53
White	0.63
Aspen	
Big tooth	0.41
Quaking	0.40
Basswood, American	0.38
Beech, American	0.68
Birch	
Sweet	0.71
Yellow	0.66
Cherry, black	0.53
Chestnut, American	0.45
Cottonwood	
Black	0.35
Eastern	0.43
Elm	
American	0.54
Rock	0.67
Slippery	0.56
Hackberry	0.57
Hickory, pecan	0.69
Hickory, true	
Mockernut	0.78
Shagbark	0.77
Magnolia, southern	0.52
Maple	
Black	0.60
Red	0.56
Silver	0.50
Sugar	0.66
Oak, red	
Black	0.66
Northern red	0.65
Southern red	0.62
Oak, white	
Bur	0.66
White	0.72
Sweetgum	0.55
Sycamore, American	0.54
Tupelo	
Black	0.54
Water	0.53
Yellow-poplar	0.46

Table 3-7A Softwood – Specific Gravity

Species	Specific gravity
Softwoods	
Baldcypress	0.47
Cedar	
Atlantic white	0.34
Eastern red	0.48
Northern white	0.31
Port-Orford	0.43
Western red	0.33
Yellow	0.46
Douglas-fir	
Coast	0.51
Interior north	0.50
Interior west	0.52
Fir	
Balsam	0.37
White	0.41
Hemlock	
Eastern	0.42
Western	0.48
Larch, western	0.56
Pine	
Eastern white	0.37
Jack	0.45
Loblolly	0.54
Lodgepole	0.43
Longleaf	0.62
Pitch	0.53
Ponderosa	0.42
Red	0.46
Shortleaf	0.54
Slash	0.61
Sugar	0.37
Western white	0.40
Redwood	
Old growth	0.41
Young growth	0.37
Spruce	
Black	0.43
Engelmann	0.37
Red	0.42
Sitka	0.42
White	0.37

wood species that is easy to cut does not necessarily develop a smooth surface when it is machined. Three ma or factors other than density can affect the production of a smooth surface during wood machining interlocked and variable grain, hard mineral deposits and reaction wood, particularly tension wood in hardwoods.

ome of these factors can be minimized by careful attention to feed rate, cutting angle and sharpness of tools. ard deposits can have a pronounced dulling effect on all cutting edges. Tension wood can cause fibrous and fu y surfaces and can be very troublesome in species of lower density.

valuations of tests of . . ardwoods is given in table 3-

Table 3–8. Some machining and related properties of selected domestic hardwoods

Kind of wood[a]	Planing: perfect pieces (%)	Shaping: good to excellent pieces (%)	Turning: fair to excellent pieces (%)	Boring: good to excellent pieces (%)	Mortising: fair to excellent pieces (%)	Sanding: good to excellent pieces (%)	Steam bending: unbroken pieces (%)	Nail splitting: pieces free from complete splits (%)	Screw splitting: pieces free from complete splits (%)
Alder, red	61	20	88	64	52	—	—	—	—
Ash	75	55	79	94	58	75	67	65	71
Aspen	26	7	65	78	60	—	—	—	—
Basswood	64	10	68	76	51	17	2	79	68
Beech	83	24	90	99	92	49	75	42	58
Birch	63	57	80	97	97	34	72	32	48
Birch, paper	47	22	—	—	—	—	—	—	—
Cherry, black	80	80	88	100	100	—	—	—	—
Chestnut	74	28	87	91	70	64	56	66	60
Cottonwood[b]	21	3	70	70	52	19	44	82	78
Elm, soft[b]	33	13	65	94	75	66	74	80	74
Hackberry	74	10	77	99	72	—	94	63	63
Hickory	76	20	84	100	98	80	76	35	63
Magnolia	65	27	79	71	32	37	85	73	76
Maple, bigleaf	52	56	80	100	80	—	—	—	—
Maple, hard	54	72	82	99	95	38	57	27	52
Maple, soft	41	25	76	80	34	37	59	58	61
Oak, red	91	28	84	99	95	81	86	66	78
Oak, white	87	35	85	95	99	83	91	69	74
Pecan	88	40	89	100	98	—	78	47	69
Sweetgum[b]	51	28	86	92	58	23	67	69	69
Sycamore[b]	22	12	85	98	96	21	29	79	74
Tanoak	80	39	81	100	100	—	—	—	—
Tupelo, water[b]	55	52	79	62	33	34	46	64	63
Tupelo, black[b]	48	32	75	82	24	21	42	65	63
Walnut, black	62	34	91	100	98	—	78	50	59
Willow	52	5	58	71	24	24	73	89	62
Yellow-poplar	70	13	81	87	63	19	58	77	67

[a]Commercial lumber nomenclature.
[b]Interlocked grain present.