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Forestry & Natural Resources

FURNITURE MANUFACTURING

Wood Moisture Calculations

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Introduction

In its natural state, wood contains cell wall substance, imbibed and free water, internal voids and extraneous materials including extractives. Although most woods are ordinarily thought of as solid and compact materials, because of their cellular structure, they are actually quite porous. Sixty-two percent of the volume of oven dry sugar maple, for example, consists of internal voids. Free water is contained in the obvious void spaces, the cell cavities, whereas imbibed water is contained in cell wall voids. The relative and absolute amounts of wood substance, imbibed and free water, and void space present in wood have a direct bearing on the physical and mechanical properties of wood and also upon its seasoning characteristics. Knowledge of the way water is held in wood and the manner in which the moisture content of the wood changes in response to changes in humidity in the atmosphere is important to furniture manufacturers since it dictates the allowances that must be made for shrinking and swelling of the wood once the furniture is placed in service. Several aspects of wood moisture relationships are discussed in this paper which should be of use to manufacturers concerned with wood/moisture phenomena. Definitions of the most important wood-moisture terms are given and methods of calculating their numerical values are discussed and illustrated by means of worked examples.

Moisture Content

The weight of moisture contained in a piece of wood expressed as a percentage of its oven dry weight is almost universally referred to as its moisture content.

Expressed mathematically

$$mc = \frac{(W_g - W_o)}{W_o} \cdot 100\%$$

where mc = moisture content

W_g = green weight of the wood

W_o = oven dry weight of the wood

Oven dry weight is the quasi-constant weight attained by wood samples dried at 105 C° (221 F°). As pointed out by MacLean (1952) and Stamm (1964), it is advantageous to define moisture content in terms of the oven dry weight of the wood since the oven dry weight is a constant value that may be determined at any time. This factor is of considerable value in numerous experiments where initially oven drying a sample to determine its moisture content would irrevocably alter its characteristics and prevent its subsequent experimental use. Furthermore, expressed as a percentage of oven dry weight, moisture content is readily envisaged since it represents the amount of moisture contained in the wood as parts by weight of water to 100 parts of wood substance. Finally, the equilibrium moisture content of many wood species at a given temperature and relative humidity is nearly the same regardless of their density or specific gravity. If moisture content were placed on some other basis such as the green weight of wood, this extremely useful approximate relationship would be lost.

Example(1)

The green weight of a specimen of red oak is 136 grams. Its oven dry weight is 100 grams. What is its moisture content?

Ans:

W_g = the green weight = 136 grams

W_o = the oven dry weight = 100 grams

Therefore,

$$mc = \frac{(136g - 100g)}{100g} \cdot 100\% = 36\%$$

When the moisture content of a piece of wood has been determined by some means other than the oven drying method, its oven dry weight can nonetheless be found by calculation. If, for example, the weight of a green sample is known to be 600 grams and its moisture content 50 percent, the oven dry weight can be calculated from the definition formula, i.e.,

$$mc = \frac{(600g - W_o)}{W_o} \cdot 100\% = 60\%$$

or,

$$W_o = 375 \text{ grams.}$$

This method is particularly useful for determining the oven dry weight of large specimens. Frequently small moisture samples can be cut from a board without ruining it for subsequent test uses. These samples can be oven dried to determine their moisture content. From this information, the oven dry weight of the entire board can be found.

Example(2)

Two sample moisture sections, one inch thick along the grain, were cut from a 1 x 4 inch by twelve foot long green sugar maple board, Figure 1. The first sample had a green weight of 68 grams and an oven dry weight of 40 grams while the second had green and oven dry weights of 72 and 43 grams, respectively. The total weight of the three remaining four foot sections of the board was 18 pounds. What was the average oven dry weight of each of these four foot lengths?

Ans:

The moisture content of the first sample was

$$mc_1 = \frac{(68g - 40g)}{40g} \cdot 100\% = 70\%$$

and the second

$$mc_2 = \frac{(72g - 43g)}{43g} \cdot 100\% = 67.4\%$$

The average of these two values is

$$mc_{avg} = \frac{(70\% + 67.4\%)}{2} = 68.7\%$$

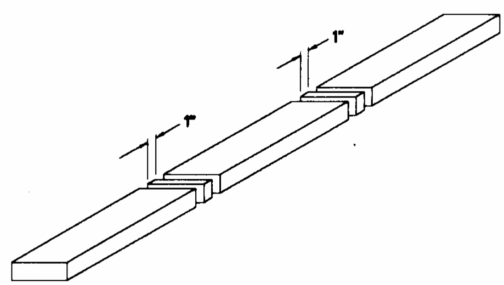

Figure 1.

Each of the three-four foot sections weighs

$$W_g = 18 \text{ lbs}/3 = 6 \text{ lbs}$$

or, in grams

$$W_g = 6 \text{ lbs x } 454\text{g/lb} = 2724\text{g}$$

The oven dry weight of each specimen is thus given by

$$\frac{(2724g - W_o)}{W_o} \cdot 100\% = 68.7\%$$

or,

$$W_o = 1614.7\text{g , or, } 3.56 \text{ lb}$$

Density and Specific Gravity

Confusion often results over the meaning of the two terms, density and specific gravity. Density means concentration of matter, measured as mass per unit volume (Hodgman, 1950), or,

$$\rho' = \frac{m}{V}$$

where p' is used to represent density, m represents mass, and V represents volume. By definition, therefore, densities can only be expressed as grams per cubic centimeter, kilograms per cubic meter, or slugs per cubic foot. In wood seasoning work, however, an engineering interpretation of density is typically used; that is, weight per unit volume, or

$$\rho = \frac{W}{V}$$

where W is the weight of a material. When defined in this way, ρ should be referred to as "weight density" to distinguish it from the physicist's "mass density." This notational precision is seldom observed, however, and which of the two terms is meant is usually left to the reader's judgment.

Weight density is unconsciously used in everyday speech. The density of water, for example, is spoken of as 62.4 pounds per cubic foot or 8.33 pounds per gallon. Frequently, however, a person will simply say, "water weighs 62.4 pounds per cubic foot." The density of wood is usually stated in pounds per cubic foot. If, for example, the weight of one board foot of green red oak is 5 pounds, then its weight density is

$$\rho = \frac{5\ lb}{bd\,ft} \cdot \frac{12\ bd\,ft}{ft^3} = \frac{60\ lb}{ft^3}$$

The density of wood is, of course, not a fixed value but depends upon the moisture content of the wood. Wood density varies greatly from species to species. According to Brown, et al. (1952) the lightest species weigh about 2-1/2 pounds per cubic foot when oven dry compared to 87 pounds per cubic foot for the heaviest. Balsa, the fourth or fifth lightest species in the world (Warring, 1966; Chudnuff, 1984) has a density as low as 4 pounds per cubic foot up to 25 pounds per cubic foot or more.

Specific gravity is defined as the ratio of the density of a material to the density of pure water, or, expressed mathematically

$$Sp.Gr. = \frac{\rho_x}{\rho_w}$$

where ρ_x refers to the density of the material in question and ρ_w to the density of pure water (usually taken at 4 C°.). It has been pointed out

(Sears and Zemansky, 1952) that the term "specific gravity" is a poor one since it has nothing to do with gravity. A more descriptive term would perhaps be "relative density."

The specific gravity of a wood specimen may be calculated by means of the formula

$$Sp.Gr. = \frac{weight\ of\ the\ specimen}{weight\ of\ equal\ volume\ of\ water}$$

If, for example, an oven-dry rectangular sugar maple specimen measures 1 centimeter along each face and weighs 0.68 grams, its sp.gr. is

$$S_o = \frac{\frac{0.68g}{1cm^3}}{\frac{1g}{1cm^3}} = 0.68$$

Although the weight of wood is almost universally taken as its oven-dry weight, the volume may be measured when the moisture content of the specimen is at any desired arbitrary value. The specific gravity of a piece of wood is not, therefore, a single-valued constant but depends instead upon the circumstances under which it was determined. Specific gravity values are highest when based upon oven dry volume measurements and least when based upon green volume measurements. As previously mentioned, it is convenient to base wood-moisture and specific gravity calculations on the oven-dry weight of the wood since it is an extreme, reproducible, constant condition that can be determined at any time. For the same reasons, specific gravity determinations are most conveniently made with either green or oven dry specimens. In the United States specific gravity values are usually based on green volume measure, but in Europe they are typically based on oven dry dimensions.

Example(3)

The oven dry weight of a sugar maple specimen is 100 grams. Its green volume, volume at 15% moisture content, and oven-dry volume are 178, 161, and 147 cubic centimeters respectively. What are the specific gravity values corresponding to these conditions?

Ans.

$$S_g = \frac{100}{178} = 0.56$$

$$S_{15} = \frac{100}{161} = 0.62$$

$$S_o = \frac{100}{147} = 0.68$$

where S_g, S_{15}, and S_o refer to specific gravity values based on volumes measured when the sample was green, at 15% moisture content, and oven dry.

In wood seasoning research it is often desirable to convert specific gravity values from one volume basis to another. To do this we make use of the fact that the volumetric shrinkage and therefore the sp. gr. of many wood species is proportional to the change in moisture content (expressed as weight) below the fiber saturation point; that is, $dV = k \cdot dW$, where dV refers to the change in volume, dW refers to the change in weight of moisture contained in the sample, and k is a constant of proportionality. When a specimen dries below the fiber saturation point (f.s.p.), dW, is given by the expression

$$dW = \frac{30 - mc}{100} \cdot W_o$$

where W_o refers to the oven dry weight of the wood and the fiber saturation point is assumed to be 30 percent. In the centimeter gram second (cgs) system of units, we might expect the volume of water lost to be numerically equal to the weight lost since 1 cm^3 of water weighs about 1 gram. When water is absorbed into wood, however, it does not retain its original volume, but is slightly compressed. As shown in Figure 2 (MacLean, 1952), the specific gravity of the water imbibed into wood at the f.s.p. is 1.115 (Skaar, 1972). The specific volume of this water is

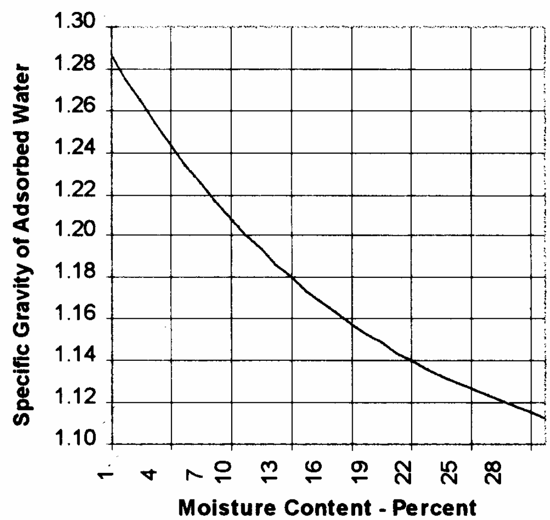

Figure 2.

$$Sp.Vol. = \frac{1}{Sp.Gr.} = \frac{1}{1.115} = 0.9$$

so that the corresponding volumetric shrinkage of the wood where $k = 0.9$ is given by

$$dV = 0.9 \cdot \frac{30 - mc}{100} \cdot W_o = 0.009 \cdot (30 - mc) \cdot W_o$$

Reducing this to a unit volume change gives

$$dv = 0.009 \cdot \frac{W_o}{V_g} \cdot (30 - mc)$$

where V_g refers to the green volume of the specimen. Finally, since

$$S_g = \frac{W_o}{V_g}$$

this expression can be written

$$dv = 0.009 \cdot S_g \cdot (30 - mc)$$

Given the green volume of the wood, V_g, the sp. gr., S_x at some lower moisture content can then be found from the expression

$$S_x = \frac{W_o}{V_g - dV}$$

Substituting the appropriate expression for dV into the above expression gives

$$S_x = \frac{W_o}{V_g - 0.009 \cdot W_o \cdot (30 - mc)}$$

Dividing top and bottom by V_g and substituting S_g for W_o / V_g gives

$$S_x = \frac{S_g}{1 - 0.009 \cdot S_g \cdot (30 - mc)}$$

Example (4)

The sp.gr., S_g, of red oak is 0.57. What is its specific gravity based on oven dry volume?

Ans.

$$S_o = \frac{0.57}{1 - 0.009 \cdot (0.57)(30)} = 0.675$$

Similarly, to calculate S_x values from specific gravities based on oven-dry volumes, dV must be added, and the following expression results

$$S_x = \frac{S_o}{1 + 0.009 \cdot S_o \cdot mc_x}$$

Example (5)

The sp.gr., S_o, of red oak is 0.68. What is the specific gravity based on green volume?
Ans.

$$S_g = \frac{0.68}{1 + 0.009 \cdot (0.68)(30)} = .57$$

To determine the sp.gr., S_x, based on volume at moisture content, mc_x, when the sp.gr., S_y, corresponding to some other moisture content, mc_y, is known, the following general formula may be used:

$$S_x = \frac{S_y}{1 + 0.009 \cdot S_y \cdot (mc_x - mc_y)}$$

Finally, when S_o and S_g, are both known, S_x may be found by a simple proportion

$$S_x = S_o - (S_o - S_g)(mc_x) / 30$$

Table 1 gives the specific gravity of a number of wood species based on both green and oven-dry volume.

Void Volume of Wood

Void Volume of Oven-Dry Wood

When wood is seasoned to prepare it for subsequent treatment with preservatives or other chemicals, it is important to know how much water must be removed from the wood before the desired amount of solution can be injected into it. As an example, a gallon of water weighs approximately 8.3 pounds and occupies 0.1337 cubic feet. If we wish to treat a charge of material with an aqueous solution and obtain a retention of 8 pounds per cubic foot, the wood must have in it an unoccupied space equal to about 13.37% of the total volume of the wood. MacLean (1952) points out, however, that even with small easily penetrated specimens, about 5 to 10 percent of the air space in the wood remains unfilled. He further states that it is usually not practical to obtain net retentions using the full cell method of treatment that fill more than 80 to 85 percent of the available air space. Using this information it can be seen that the required void volume is 16 to 20 percent greater than calculated above.

To calculate this unoccupied space, which is usually referred to as void volume and is expressed as a fraction of the total specimen volume, it is first necessary to calculate the fractional volume of solid wood substance present. If, for convenience, we accept 1.50 as the specific gravity of oven-dry wood substance, the maximum density of a completely solid wood specimen devoid of pores would be 1.50g/cm^3.

Wood, as it occurs naturally, is porous, however, and contains many void spaces. Because of its porosity, the oven dry density of a unit cube of natural wood will be less than the density of pure wood substance. Since such a unit cube of natural wood contains essentially nothing more than wood substance and air, the fractional amount of solid wood substance present in the cube is given by the ratio of the oven-dry density of the natural wood to the oven-dry density of pure wood substance. Algebraically, the solid volume, v_s, can be calculated as

$$v_s = \frac{W_o}{W'_o} = \frac{S_o}{S'_o} = \frac{S_o}{1.50}$$

where W_o = the oven dry weight of a unit cube of dry wood, and W'_o = the oven dry weight of a unit cube of dry wood substance = 1.50 grams (as long as cgs units are used since specific gravity and density are numerically equal in this system of units). If we now consider an actual wood specimen such as sugar maple which has an oven-dry density of 0.68g/cm^3, we find that the fractional solid volume is

$$v_s = \frac{0.68}{1.50} = 0.453$$

or, expressed as a percentage, we may say that solid wood substance occupies 45.3 percent of the total volume of oven-dry sugar maple.

If the solid volume of oven-dry wood is given by the ratio $S_o / 1.50$, then the void volume, v_v, must be given by the expression

$$v_v = 1 - \frac{S_o}{1.50}$$

where 1 is the total volume of a unit cube. Referring to the example above, since the fractional solid volume of oven-dry sugar maple is 0.453, it follows that its fractional void volume is 1 - 0.453, or 0.547. In other words, 54.7 percent of the total volume of oven dry sugar maple is void space.

Example (6)

If the sp.gr., Sg, of red oak is .57, what is its fractional void volume in the oven-dry condition?

Ans.

To solve the problem we must first calculate, S_o, the oven-dry sp.gr. of the red oak. Applying the expression previously derived gives

$$S_o = \frac{0.57}{1 - 0.009 \cdot (0.57)(30)} = 0.67$$

The fractional void volume of the wood may then be calculated as follows:

$$v_v = 1 - \frac{0.67}{1.50} = 0.55$$

Void Volume of Wood at Any Moisture Content

Whereas determining the fractional void volume of oven-dry wood is a relatively straightforward procedure, calculating void volumes at other moisture content levels is more complex since the effects of the included water must be considered. The included water has two effects. Firstly, it causes the wood to swell, and secondly, it adds its volume to the volume of wood substance present. As was previously shown, that part of the water which is absorbed into the cell walls is compressed. Three different contributions to solid volume (where solid volume now includes the water present) must thus be appraised:

1) the space occupied by cell wall substance
2) the space occupied by imbibed water
3) the space occupied by free water

The fractional volume, v_1, of cell wall wood substance present in wood at some moisture content level, mc_x , is given by the expression

$$v_1 = \frac{S_x}{1.50}$$

where S_x is the sp.gr. of the wood sample based on volume measured at a specific moisture content level. Note that S_x rather than S_o is required in this expression.

Next, consider a unit cube of wood which has a moisture content of mc_x percent. The amount of cell wall substance in this cube is given by the oven-dry weight, and the solid volume is then given by the ratio of the oven-dry weight of the cell wall substance contained in this unit cube to the weight of a unit volume of solid cell wall substance. The weight of the imbibed water, W_x, is

$$W_x = \frac{S_x \cdot mc_x}{100}$$

The absolute fractional volume is then calculated by dividing W_x by the density of the water, ρ_x, so that the volume occupied by the imbibed water, v_2, is

$$v_2 = \frac{S_x \cdot mc_x}{100\rho_x}$$

where mc_x equals the current moisture content which is equal to or less than the f.s.p., and ρ_x is the density of the imbibed water as shown in Figure 2.

The fractional volume of free water present, v_3, is equal to

$$v_3 = \frac{S_x \cdot mc_y}{100}$$

where mc_y is the moisture content above f.s.p. That is, if a specimen had a moisture content of 53%, mc_y would equal 23% (assuming f.s.p is 30%). This water is not compressed, and hence its volume is taken the same as that of pure water.

The total fractional volume, v_T, of materials in a unit cube of wood at some moisture content mc_x, is, therefore, equal to the sum of the partial volumes, i.e.,

$$v_T = v_1 + v_2 + v_3$$

It follows, as before, that the remaining fractional void volume is 1 minus this quantity, i.e.,

$$v_v = 1 - (v_1 + v_2 + v_3)$$

Substituting the previously derived expressions for partial volumes into this equation and simplifying yields

$$v_v = 1 - S_x \cdot \left[\frac{1}{1.50} + \frac{mc_x}{100\rho_x} + \frac{mc_y}{100} \right]$$

When the moisture content is substantially above f.s.p., compression of the imbibed water can usually be neglected. The above formula may then be simplified to

$$v_v = 1 - S_x \cdot \left[\frac{1}{1.50} + \frac{mc}{100} \right]$$

where mc is the total moisture content.

Example (7)

What is the void volume of red oak at 60% moisture content?

Ans.

The sp.gr., S_g, of green red oak is 0.57; similarly, the sp.gr. of the imbibed water is 1.115. Therefore,

$$v_v = 1 - 0.57 \cdot \left[\frac{1}{1.50} + \frac{0.3}{1.115} + 0.3\right] = 0.296.$$

Let us now compare this with the value obtained using the second expression

$$v_v = 1 - 0.57 \cdot \left[\frac{1}{1.50} + 0.6\right] = 0.278$$

This latter value differs from the first by only 7.32 percent.

Example (8)

What is the void volume of basswood at 10% moisture content?

Ans.

The S_o of basswood equals 0.40 and S_g equals 0.32. Using a straight line approximation,

$$S_x = 0.40 - \left[\frac{10}{30}\right] \cdot (0.40 - 0.32) = 0.373$$

From Figure 2 it is seen that $\rho_{10} = 1.20 g/cm^3$. Thus,

$$v_v = 1 - 0.373 \cdot \left[\frac{1}{1.50} + \frac{0.1}{1.2}\right] = 0.72$$

If the previous calculations appear somewhat confusing, an alternative approach, based upon the sp.gr. of wood substance at current moisture content rather than oven-dry conditions, may be of help in visualizing and calculating void volume and maximum moisture content. It is first necessary to calculate the sp.gr. of wood substance at current moisture content

The weight of moisture absorbed by an oven-dry cube of wood substance is given by the expression

$$dW'_x = \frac{mc_x W'_o}{100} \qquad mc_x \leq 30$$

where dW'_x is the weight of water, W'_o is the oven-dry weight of the wood substance, and mc_x is the current moisture content Reducing this to unit volume and unit weight, dw'_x, gives

$$dw'_x = \frac{mc_x}{100} \cdot \frac{W'_o}{V_o} = \frac{mc_x}{100} \cdot S'_o = \frac{1.50 \cdot mc_x}{100}$$

where dw'_x is weight per unit volume of the water, V_o is the oven-dry volume, and S'_o is the sp. gr. of oven-dry wood substance, i.e., S'_o = 1.50. If the absorbed water were not compressed, the change in volume of a unit cube owing to the moisture would be given by $dv = dw$. Since it is compressed, however, we must account for the reduced volume, either by dividing dw'_x by an average value of density for imbibed water, 1.115, or by an exact value for density taken from the graph shown by MacLean. Thus,

$$dv_x = \frac{1.50}{\rho_x} \cdot \frac{mc_x}{100}$$

where dv_x is change in volume adjusted to current moisture content on a unit basis and ρ_x is the density of imbibed water at the current moisture content. The volume of the original unit cube of oven dry wood substance is thus increased to

$$v = 1 + dv = 1 + \left[\frac{1.50}{\rho_x} \cdot \frac{mc_x}{100} \right]$$

and the new sp.gr. of the wood substance is

$$S'_x = \frac{W'_o}{v} - \frac{1.50}{1 + \left[\frac{1.50}{\rho_x} \cdot \frac{mc_x}{100} \right]}$$

where S'_x is the sp.gr. of wood substance at the current moisture content.

Example (9)

What is the sp.gr. of green wood substance?

Ans.

In the green state, mc_x, as here defined, is taken to be 30%; S'_o as before has a value of 1.50, and ρ_x = 1.115 at 30 percent moisture content. Therefore,

$$S'_g = \frac{1.50}{\left[1 + \frac{1.50}{1.115} \cdot \frac{30}{100}\right]} = \frac{1.50}{1 + 0.404} = 1.069$$

Example (10)

What is the sp.gr. of wood substance at 10% moisture content?

Ans.

At 10% moisture content the density of the imbibed water (read from the graph) is 1.20. Therefore,

$$S'_{10} = \frac{1.50}{\left[1 + \frac{1.50}{1.20} + \frac{10}{100}\right]} = \frac{1.50}{1 + 0.125} = 1.333$$

If we now define solid volume V'_s to include both wood substance and imbibed water, then the fractional solid volume of a cube of wood below the fiber saturation point can be expressed as

$$V'_s = \frac{S_x}{S'_x}$$

and the fractional void volume, V'_v, up to the fiber saturation point as

$$V'_s = 1 - \frac{S_x}{S'_x}$$

Above the fiber saturation point, void volume must be reduced by the amount of free water present; therefore

$$V'_v = 1 - \frac{S_x}{S'_x} - \frac{mc - 30}{100} \cdot S_x$$

or,

$$V'_v = 1 - \frac{S_x}{S'_x} - \frac{mc_{y \cdot S_x}}{100}$$

where $mc_y = mc - 30$. Rearranging terms gives

$$V'_v = 1 - S_x \cdot \left[\frac{1}{S'_x} + \frac{mc_y}{100}\right]$$

This void volume expression, V'_v, is identical in form to the one previously derived V_v, except that the first two terms inside the parenthesis of the expression for V_v have been replaced by $1/S'_x$. It follows therefore, that

$$\frac{1}{S'_x} = \frac{1}{S'_o} + \frac{mc_x}{100\rho}$$

or,

$$S'_x = \frac{100 \cdot \rho \cdot S'_o}{100 \cdot \rho + mc_x \cdot S'_o} = \frac{S'_o}{1 + \left[\dfrac{mc_x \cdot S'_o}{100 \cdot \rho}\right]} - \frac{1.50}{1 + \left[\dfrac{1.50 \cdot mc_x}{100\rho}\right]}$$

as was previously shown.

Example (11)

What is the void volume of yellow birch, $S_o = .66$, at 10% moisture content?

Ans.

The sp.gr. of yellow birch at 10% moisture content is

$$S_{10} = \frac{1}{1 + \left[\dfrac{0.66}{1.20} \cdot \dfrac{10}{100}\right]}$$

where the density of imbibed water at 10% moisture content is 1.20g /cm^3. Solving gives

$$S_{10} = \frac{0.66}{1 + 0.055} = 0.626$$

From the previous example, $S_{10} = 1.333$. Therefore,

$$V'_v = 1 - (0.626 / 1.33) = 1 - 0.470 = 0.530$$

Had we worked this in the previous way

$$V_v = 1 - 0.626 \cdot \left[\frac{1}{1.50} + \frac{10}{1.2 \cdot (100)}\right]$$

or,

$$V_v = 1 - 0.626 \cdot (0.667 + 0.835) = 1 - 0.626(0.751) = 1 - 0.470 = 0.530$$

as before.

Maximum Moisture Content of Wood

Since the void volume of wood is zero when it is completely saturated with water, the above equations can be solved for maximum moisture content simply by setting V_v equal to zero. Solving the second expression for mc_{max} with $V_v = 0$ and $S_x = S_g$ gives

$$mc_{max} = \left[\frac{1}{S_g} - \frac{1}{1.50}\right] \cdot 100\%$$

or,

$$mc_{max} = \left[\frac{1.50 - S_g}{1.50 \cdot S_g}\right] \cdot 100\%$$

Example (12)

What is the maximum possible moisture content of Eastern white pine?

Ans.

The S_g of white pine equals 0.34. Therefore,

$$mc_{max} = \left[\frac{1.50 - 0.34}{1.50 \cdot 0.34}\right] \cdot 100\% = \frac{1.16}{0.51} \cdot 100\% = 227\%$$

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Wood Species	Specific Gravity		Wood Species	Specific Gravity	
	Oven-dry Volume	Green Volume		Oven-dry Volume	Green Volume
Ash, commercial white	.55	.64	Silver	.44	.51
Aspen, quaking	.35	.41	Sugar	.56	.68
Basswood, American	.32	.40	Oak:		
Baldcypress	.42	.48	Red[4]	.57	.58
Beech, American	.56	.67	White[5]	.60	.72
Birch, yellow	.55	.66			
Cherry, black	.47	.53	Pine:		
Chestnut, American	.40	.45	Loblolly	.47	.54
Cottonwood:			Lodgepole	.38	.43
Eastern	.37	.43	Longleaf	.54	.62
Northern black	.32	.37	Eastern white	.34	.37
Douglas-fir:			Red	.41	.51
Coast type	.45	.51	Ponderosa	.38	.42
Intermediate type	.41	.47	Shortleaf	.46	.54
Rocky Mountain type	.40	.45	Slash	.56	.66
Elm:			Sugar	.35	.38
American	.46	.55	Western white	.36	.42
Rock	.57	.66	Redcedar:		
Slippery	48	.57	Eastern	.44	.49
Fir:			Western	.31	.34
Balsam	.34	.41	Redwood	.38	.42
Commercial white[1]	.36	.41	Spruce:		
Hackberry	.49	.56	Eastern[6]	.38	.43
Hemlock:			Engelmann	.32	.35
Eastern	.38	.43	Sitka	.37	.42
Western	.38	.44	Sugarberry	.47	.54
Hickory:			Sweetgum	.44	.53
Pecan[2]	.59	.64	Sycamore, American	.46	.54
True[3]	.64		Tamarack	.49	.56
Honeylocust	.60	.67	Tupelo:		
Larch, western	.50	.59	Black	.46	.55
Locust, black	.66	.71	Water	.46	.52
Maple:			Walnut, black	.51	.56
Bigleaf	.44	.51	White-cedar, northern	.29	.32
Black	.52	.62	Yellow-poplar	.38	.43
Red	.49	.55			

[1]Average of grand fir and white fir. [2]Average of bitternut hickory, nutmeg hickory, water hickory, and pecan. [3]Average of shellbark hickory, mockernut hickory, pignut hickory, and shagbark hickory. [4]Average of black oak, laurel oak, pin oak, northern red oak, scarlet oak, southern red oak, swamp red oak, water oak, and willow oak. [5]Average of bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak. [6]Average of black spruce, red spruce, and white spruce.

Table 1. Specific gravity of selected woods based on green and oven-dry volume.