Chapter 6. Nonveneer Panel Products: Particleboard, Hardboard, Medium Fiberboard, OSB/Waferboard, and Insulation Board

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Unlike plywood, which is made from veneer, these panel or "board" products are made from chips, wafers, strands, flakes, and particles of wood or from wood fiber after pulping or refining. Collectively, they are often called *composition, reconstituted* or *nonveneer panels,* or *boards*. Another widely used term for this collection of panel products is *composites*. Adhesives and other substances are often mixed with the furnish to create desired properties.

Classification

Depending on species, particle type, and orientation, the type and amount of adhesives and additives used, and thickness and density to which the board is pressed, a very wide spectrum of these products is possible. Agencies reporting statistics often combine them into other groups. For example, OSB/waferboard is often combined with softwood plywood into a grouping called *structural panels*. Table 6-1 presents a simple classification based on panel density. The reader should consult the *Wood Handbook* (USFS 1987), Maloney (1977), and Suchsland and Woodson (1990) for further details on specifications, uses, and processes for these products. The references also include the U.S. Department of Commerce standards for these products.

Measurement

Standard Reporting Basis

Square Foot Basis (SF). Like plywood statistics, nonveneer panel statistics are generally reported in North America in square feet of a standard thickness basis. This represents a piece one foot square and 1/8, 3/8, 1/2, or 3/4 inch thick depending on the product. Respectively, these represent 1/96, 1/32, 1/24, and 1/16 of a cubic foot. Table 6-1 presents the standard thickness basis for each of these products and the metric equivalents.

Square Meter, 1 mm Basis. The standard basis for reporting these products in countries using the metric system is the square meter, 1 mm basis. This represents a piece 1 m square and 1 mm thick or 1/1,000 of a cubic meter.

Table 6-1. *Basic measurements of nonveneer panels.*

Product	Thickness standard (in)	Thickness standard (mm)	Specific gravity	Density (lb/ft^3)	Formula to convert SM_t to thickness standard
OSB/waferboard	3/8	9.5	0.48-0.80	30-50	$SM_t * t / 0.375$
Particleboard	3/4	19.0			$SM_t * t / 0.750$
Low			0.40-0.59	25-37	
Medium			0.59-0.80	37-50	
High			0.80-1.12	50-69	
Insulation board	1/2	12.7	0.16-0.50	10-31	$SM_t * t / 0.500$
Hardboard	1/8	3.2			$SM_t * t / 0.125$
Medium			0.50-0.80	31-50	
High			0.80-1.28	50-80	
Densified			1.36-1.44	85-90	
MDF	3/4	19.0	0.50-0.80	31-50	$SM_t * t / 0.750$

Volume of Nonveneer Panels

The methods for converting surface measures and calculating volume of these products are similar to those used for plywood.

Converting Surface Measure of Any Thickness to the Standard Thickness Basis. Like the method for plywood, to convert surface measure from any thickness (SM_t) to the standard basis for the product, divide the actual thickness (t) in inches by the standard thickness in inches and multiply by the surface measure. The last column of Table 6-1 shows the equation for each product. Table 5-1 summarizes conversion of actual panel thickness to each of the four thickness standards. See also Example 1.

Note that any one of the formulas can be used to standardize all panel products to the same thickness basis. In its assessment of the U.S. timber situation, the USFS expresses all of these panel products on the 3/8 inch basis (Appendix 2).

Cubic Foot Calculation. The general formula developed for plywood (Chapter 5, p. 70) can be used:

$$ft^3 = SM_t * t / 12 = 0.08333 * t * SM_t .$$

Therefore, Table 5-4 can be used to convert a quantity of panels of a given thickness to cubic feet or cubic meters. See also Example 2.

Metric Calculation. Outside North America, nonveneer panels are produced in metric sizes; width (W) and length (L) are in meters, and thickness (t) in millimeters. Statistics are generally reported in square meters surface measure (on a 1 mm basis) or cubic meters. Formulas are

SM_t = $L * W$ = surface measure, m^2, of original thickness.

SM_1 = $SM_t * t$ = surface measure, m^2, 1 mm basis.

m^3 = $SM_t * t / 1{,}000 = SM_1 / 1{,}000$.

Wood Requirements

This section presents a method for estimating the quantity of solid wood equivalent needed to produce a unit quantity of a nonveneer panel product. Since these products are produced from small wood elements, the raw material need not be in the form of roundwood logs. The USFS timber assessment provides national averages for wood required (cubic feet roundwood equivalent) to produce one MSF 3/8 inch basis or one cubic foot of these products (Appendix 2).

Example 1

Convert 2,500 ft^2 of 3/4 inch insulation board to the 1/2 inch standard basis, using the formula in Table 6-1.

$$SF_{1/2} = SM_t * t / 0.5 = 2{,}500 * 0.75 / 0.5 = 3{,}750$$

or multiply 2,500 ft^2 by the factor 1.5000 in column 5 of Table 5-1.

Convert 1,500 ft^2 of 7/16 inch particleboard to the 3/4 inch standard basis, using the formula in Table 6-1.

$$SF_{3/4} = SM_t * t / 0.75 = 1{,}500 * (7/16) / 0.75 = 875$$

or multiply 1,500 ft^2 by the factor 0.5833 in column 6 of Table 5-1.

Example 2

Convert 1,500 ft^2 of 7/16 inch particleboard to cubic feet:

$$ft^3 = 0.08333 * (1{,}500 * 7/16) = 54.7$$

or multiply 1,500 ft^2 by the factor 0.03646 in column 3 of Table 5-4.

Manufacturing processes for nonveneer panels are often referred to as "wet" or "dry." In a dry process, the conveying medium for the wood particles or fibers is air; in a wet process it is water. Particleboard and waferboard processes are dry, and insulation board processes are wet. Hardboard and medium density fiberboard (MDF) may be manufactured either way, although the dry process predominates in the manufacture of MDF.

Process Recovery

Conversion efficiency of nonveneer panels is most meaningfully expressed as a percentage by weight of the original wood input. Conversion efficiency of these products depends on the type of raw material (logs or mill residues), species mix, process used, and board density and thickness (Tables 6-2, 6-3). OSB/waferboard typically uses roundwood logs that are not suited for lumber or plywood. These are processed by machines to create flakes or strands with a particular geometry. A major source of loss is flakes that are rejected because of small size. Particleboard, which often uses mill residues such as sawdust, planer shavings,

Table 6-2. *Nonveneer panel process conversion efficiencies (percentage of acceptable furnish).*

Product	Process	Recovery (%)	Loss: Solubles, Fines (%)	Loss: Sander Dust (%)
Insulation board	Wet	90-95	5-10	—
Hardboard	Wet	95	5	—
	Dry	90-95	—	5-10
	Masonite	85	15	—
MDF	Wet	95	5	—
	Dry	90-95	—	5-10
Particleboard, OSB, etc.	Dry	90-95	—	5-10

Table 6-3. *Nonveneer panel process variables for green wood requirements.*

Variable	Symbol	OSB and waferboard	Particle-board	Medium density fiberboard	Hardboard	Insulation board
Board density (lb/ft^3, kg/m^3)	d	40-45	40-50	40-45	50-60	20-30
Moisture content (%)	MC_w	4	6	6	8	8
Volumetric shrinkage (%)	V	8	8	8	8	8
Raw material loss (%)	f	20	1	3	5	5
Adhesive and additive (%)	a	2	6	10-12	8	8
Sander loss (%)	S	0	6	6	0	0
Trim loss (%)[a]	T	5	5	10	10	10

Source: Adapted from Nielson et al. (1985).

[a]The trim loss percentage varies with the size of the panel as pressed. The common 4' x 8' panel is often made in an 8' x 16' or 8' x 24' press.

Note: These values should be regarded as general guidelines. Actual values vary among manufacturers due to differences in raw material, technology, and quality control.

and so forth, mills these to a small size such that much less loss occurs due to rejects. Insulation board, hardboard, and MDF may use either roundwood logs or mill residues which are converted to fiber feedstock by thermomechanical pulping processes that generally have a yield in excess of 90%. The major source of wood fiber loss in the manufacture of wet-process panels is from wood fiber that is partly solubilized and lost through the screen during the mat forming process. These residues are usually converted to other salable products.

Dry-process nonveneer panels are often sanded after pressing. The percentage of volume lost to sanding depends on board thickness, since the thickness removed by the sander is usually constant (about 0.060 inch). In the case of OSB, relatively little production is sanded. Depending on the type of product and process, some or all of the sander dust may be recycled.

Formula for Estimating Wood Requirements

Calculation of green solid wood equivalent required to produce a nonveneer panel product depends on many factors. An approximation can be obtained by combining process recovery, board density, species density, adhesive/additive weight, and moisture content/shrinkage data. Table 6-3 provides rough estimates of these variables; a particular manufacturer's recipe may deviate substantially from values in the table. Note that the sander and trim loss fractions are gross losses that should be reduced depending on the degree of recycling of these residues back into the process. (See Example 3.)

The volume of green wood required to produce 1,000 ft^2 or 1,000 m^2 is:

Imperial

$$GWR_I = [1{,}000 * t * d * (1 - MC_w/100 - a/100)] / [12 * SG_g * 62.4 * (1 - S/100 - T/100) * (1 - f)]$$

Metric

$$GWR_M = [t * d * (1 - MC_w/100 - a/100)] / [SG_g * 1{,}000 * (1 - S/100 - T/100) * (1 - f)]$$

where

GWR_I = green solid wood requirement, cubic feet, per 1,000 square feet of finished panel

GWR_M = green solid wood requirement, cubic meters, per 1,000 square meters of finished panel

f = wood raw material loss, percent of wood input volume

SG_g = wood specific gravity of species used, green volume basis (see Chapter 1)

a = percent of product weight due to additives and adhesives

MC_w = moisture content of finished panel on a total weight basis (see Chapter 1)

S = percent loss during sanding

T = percent loss in trimming panel to size

t = panel thickness, in inches or millimeters.

Derivation of these formulas is detailed in the box on page 82.

Weight of Nonveneer Panels

Densities of these panels vary depending on the manufacturer and species. Table 6-1 presents the typical range of specific gravity and density for these products. Actual board densities are often indicated by the manufacturer and are based on the moisture content as shipped, usually 6 to 8% MC_{od}. If the density is known, it is easy to calculate weight. (See Example 4.) In the absence of manufacturer's label information, an average density must be assumed, and various statistical agencies have their own assumptions. For example, FAO assumes the following:

	Specific gravity	Density (lb/ft^3)
Particleboard	0.65	40
Fiberboard:		
Compressed	0.95	60
Noncompressed	0.25	15

In the absence of such assumptions, the midrange of the densities given in Table 6-1 can be used.

Example 3

Estimate the cubic foot volume of lodgepole pine roundwood required to produce 1,000 ft^2 of 3/4 inch OSB having a panel density of 40 lb/ft^3.

Specific gravity	SG_g	=	0.38 (Table 1-1)
Panel density	d	=	40 lb/ft^3
Panel moisture content	MC_w	=	4% (Table 6-3)
Furnish rejects	f	=	20% (Table 6-3)
Adhesive/additive	a	=	4% (Table 6-3)
Sanding loss	S	=	0% (Table 6-3)
Panel trim	T	=	5% (Table 6-3)

$$GRW_I = [1{,}000\ (0.75)\ 40\ (1 - \frac{4}{100} - \frac{4}{100})] / [12\ (1 - \frac{0}{100} - \frac{5}{100})\ (1 - \frac{20}{100})\ (0.38)\ (62.4)] =$$

128 ft^3 roundwood to yield 1,000 ft^2 3/4 inch OSB.

If this is converted to 1,000 ft^2 on 3/8 inch basis, the need is 63.8 ft^3.

The USFS timber assessment (Appendix 2) estimates 62.3 ft^3 / MSF 3/8 inch basis as a weighted national average for all species and processes making OSB.

Example 4

Calculate the weight of 100 panels of 5 by 10 foot 15/16 inch particleboard having a density of 40 lb/ft^3 according to the manufacturer's label.

Surface measure of the panels = 100 * 5' * 10' = 5,000 ft^2.

Table 5-4, column 3, indicates that one square foot of 15/16 inch panel has a cubic volume of 0.07812 ft^3. Therefore, the total cubic foot volume is

5,000 ft^2 * 0.07812 ft^3/ft^2 = 390.6 ft^3.

Multiplying by the density gives

390.6 ft^3 * 40 lb/ft^3 = 15,624 lb.

Derivation of Formulas for Green Wood Requirement

The amount of solid green wood required to produce 1,000 square feet (1,000 square meters) of a nonveneer panel product can be estimated using the following procedure, which is based on formulas given by Nielson et al. (1985). More sophisticated approaches can be used, but the one presented gives reasonable values using relatively simple data. The procedure is divided into three parts. Part A starts with a volume of solid green wood and reduces it to weight of usable furnish. Part B works backward from the finished panel to estimate the weight of usable furnish needed. Part C combines the equations from parts A and B into a general equation.

Part A. Converting a volume of solid green wood to net usable furnish for making panels involves loss due to rejects and screening and the specific gravity of the species used.

1. *Imperial:* $UWOD_I = GWR_I * (1 - \frac{f}{100}) * SG_g * 62.4$

   $UWOD_I$ = oven-dry weight of usable furnish, in pounds
   GWR_I = volume of solid green wood, in cubic feet
   f = percent wood loss due to screening, rejects
   SG_g = specific gravity of species used (see Chapter 1)

2. *Metric:* $UWOD_M = GWR_M * (1 - \frac{f}{100}) * SG_g * 1{,}000$

   $UWOD_M$ = oven-dry weight of usable furnish, in kilograms
   GWR_M = volume of solid green wood, in cubic meters

Part B. Amount of wood furnish (WF) required to make finished panels:

1. Calculate panel volume and multiply by panel density to estimate panel weight.

   a. *Imperial:* Convert 1,000 square feet of panel to weight in pounds. Let

   WF_I = finished panel weight (lb) d = panel density (lb/ft^3) t = panel thickness (inches)
   $WF_I = 1{,}000 * t / 12 * d$.

   b. *Metric:* Convert 1,000 square meters of panel to weight in kilograms. Let

   WF_M = finished panel weight (kg) d = panel density (kg/m^3) t = panel thickness (mm)
   $WF_M = 1{,}000 * t / 1{,}000 \quad d = t * d$.

2. Calculate the amount of oven-dry wood in the panel by subtracting panel moisture content and additive materials (adhesives, etc.). Let

   MC_W = panel moisture content percent, total weight basis (see Chapter 1)
   a = percent additives in panel by weight.

   a. *Imperial:* WOD_I = oven-dry weight of wood furnish in finished panel (lb).

   $$WOD_I = WF_I * [1 - (\frac{MC_W}{100} + \frac{a}{100})] = \frac{1{,}000}{12} * t * d * (1 - \frac{MC_W}{100} - \frac{a}{100}).$$

   b. *Metric:*

   WOD_M = oven-dry weight of wood furnish in finished panel (kg).

   $$WOD_M = WF_M * [1 - (\frac{MC_W}{100} + \frac{a}{100})] = t * d * (1 - \frac{MC_W}{100} - \frac{a}{100}).$$

3. Increase the wood in the finished panel to account for sanding and trimming losses. Let

   S = percent sander loss T = percent trimmer loss

   a. *Imperial:*

   $$UWOD_I = WOD_I / [1 - (\frac{S}{100} + \frac{T}{100})] = [1{,}000 * t * d * (1 - \frac{MC_W}{100} - \frac{a}{100})] / [12 * (1 - \frac{S}{100} - \frac{T}{100})].$$

   b. *Metric:*

   $$UWOD_M = WOD_M / [1 - (\frac{S}{100} + \frac{T}{100})] = [t * d * (1 - \frac{MC_W}{100} - \frac{a}{100})] / (1 - \frac{S}{100} - \frac{T}{100}).$$

Part C. The equations from parts A and B are equivalent expressions for the oven-dry weight of furnish used to make panels. Combining and simplifying leads to the following expressions for volume of solid green wood needed.

1. *Imperial:* Combine equations A.1 and B.3a:

$$GRW_I, ft^3 = [1{,}000\ t * d * (1 - \frac{MC_W}{100} - \frac{a}{100})] \ / \ [12 * (1 - \frac{S}{100} - \frac{T}{100}) * (1 - \frac{f}{100}) * SG_g * 62.4].$$

2. *Metric:* Combine equations A.2 and B.3b:

$$GRW_M, m^3 = [t * d * (1 - \frac{MC_W}{100} - \frac{a}{100})] \ / \ [1{,}000 * (1 - \frac{S}{100} - \frac{T}{100}) * (1 - \frac{f}{100}) * SG_g].$$