

# Heat Capacity and Its Variation with Moisture Content for Plywood and Oriented Strand Board Sheathing Produced by North American Mills

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## Abstract

The heat capacity of panels used for house sheathing is an important property that allows the hygrothermal modeling of thermal mass and the calculation of heating and cooling rates of certain types of walls. To our knowledge, this article presents the first data in over four decades for the measurement of heat capacity across a range of moisture content values. Although some estimates of panel heat capacity exist, few, if any, have been reported for mills across North America and across a range of moisture contents. The data clearly show the dependence of heat capacity on moisture content. They also show that solid wood and panel heat capacity values are similar at low moisture contents but diverge as moisture content increases. The variation in heat capacity with moisture content is large enough so that it should be considered when determining hygrothermal efficiency in walls containing plywood or oriented strand board or when developing hygrothermal models.

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Our primary goal was to determine how the heat capacity of plywood and oriented strand board (OSB) sheathing varies with moisture content (MC) between oven-dry and about 18 percent, dry basis. The MC of wall sheathing can change seasonally and with conditions inside the structure due to air conditioners, weather, cooking practices, and showers. As MC changes, the thermal “storage” properties change, affecting thermal efficiency. Because both plywood and OSB are commonly used for building manufacture, we tested both over a wide range of MCs and from 23 manufacturing plants across North America. Despite its importance, there have been no reported measurements of the heat capacity of either plywood or OSB wall sheathing for over 40 years, and existing data do not cover a broad range of MCs or panels from geographically disperse areas. The heat capacity or “thermal mass” is the primary reason that log homes can remain comfortable during both the winter and summer and one of the reasons why wood sheathing is a good choice in wall construction. We believe that the data reported will be of use in hygrothermal modeling, such as that done by Hoes and Hensen (2016), Li et al. (2009), and others predicting the performance of light frame and other structures. The data will also be useful in predicting the heat capacity of composite core cross-laminated timber panels.

Heat capacity and specific heat capacity are terms that are used interchangeably. Ignoring units, at root, the heat capacity is a measure of the energy input to the temperature rise of a material. The most common definition is that the heat capacity of a material is the energy or enthalpy required

to raise the temperature of a mass by one degree (Tilley 2004). Most heat capacity measurements are taken across a range of temperatures, and the result should be called the mean heat capacity. As discussed by TenWolde et al. (1988), there is some confusion in the literature about the use of the terms specific heat capacity and heat capacity. In this article, we use the common definition of heat capacity and adopt calories per gram per °C (cal/g/°C) as the unit of measure. In addition, as discussed briefly below, the heat capacity measured at constant pressure ( $C_p$ ) and the heat capacity at constant volume ( $C_v$ ) are not the same. Skaar (1988) reports the ratio of  $C_v/C_p$  to be 0.94. In this article the measurements of the heat capacity,  $C$ , refer to  $C_p$ .

The initial studies of heat capacity were done by Petit and Dulong (1819), who concluded that the atoms of all simple bodies have exactly the same capacity for heat. They reached their conclusion after studying 13 pure elements and multiplying the measured heat capacity by the atomic weight as it was understood at that time. Their work eventually led to Equation 1, which is still a good

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approximation for most well-defined compounds and elements that are near room temperature.

$$C_v = 3R = 25 \text{ J/K/mol} \quad (1)$$

where

$C_v$  = the constant volume heat capacity (J/K/mol), and

$R$  = the universal gas constant, 8.314 J/K/mol.

Several problems arose with Equation 1 as more information was gathered about the nature of thermal energy and material structure. Later experiments found that heat capacity, even at modest temperatures, was a function of temperature and the Petit and Dulong approach failed badly above room temperature (Tilley 2004). Also, as noted by Ward and Skaar (1963), materials expand as they are heated, and some of the input energy is lost in the work of expanding the solid. The work of expansion leads to a difference between the heat capacity at constant volume,  $C_v$ , and the heat capacity at constant pressure,  $C_p$ .

We briefly introduce some of the later work on heat capacity by Debye (1912) because his theory was used by both Ward and Skaar (1963) and Nanassy and Szabo (1978) to explain their results. The introduction of quantized energy in solids led to the concept of phonons. Long wavelength phonons give rise to sound and short wavelength phonons give rise to heat. Theory and measurement of heat capacity differed until Debye (1912) improved the calculation by assuming that phonons are coupled, not independent. The currently used equation from Debye's theory for heat capacity across a broad range of low to high temperature is shown as Equation 2 (Tilley 2004):

$$C_V = 9R \left( \frac{T}{\Theta_D} \right)^3 \int_0^{\Theta/T} \frac{x^4 e^x}{(e^x - 1)} dx \quad (2)$$

where

$$x = hv/kT,$$

$$\Theta_D = hv_D/k,$$

$\Theta_D$  = Debye temperature,

$v_D$  = Debye frequency,

$R$  = gas constant,

$k$  = Boltzmann constant,

$T$  = temperature in Kelvin,

$h$  = Planck's constant,

$v$  = vibration frequency, and

$C_V$  = heat capacity.

Few data are reported for the heat capacity of wood-based panels, but Ward and Skaar (1963) used Debye's theory in their discussion of waferboards. Their apparatus was a variable temperature system in which the rate of energy flow was measured by the temperature rise of a heat sink. The variable temperature allowed them to estimate the thermal conductivity coefficient,  $k$ , and the specific heat,  $C$  (cal/g/°C), for a series of flat-platen pressed waferboards. After regressing the data, they obtained the equation  $C = 0.310 + 0.0202T$ , where  $T$  was valid over the range of -40°C to +40°C. The boards were about 8.3 percent MC when measured.

The values of heat capacity measured and predicted using Debye's approach by Ward and Skaar were substantially

higher than any data for solid wood, and they suggested that the adhesive resin might be responsible for the higher values. Nanassy and Szabo (1978) adopted Ward and Skaar's explanation of heat capacity from Debye while using a transient method of measuring thermal conductivity and heat capacity of waferboards bonded by phenol-formaldehyde (PF) and spent sulfite lignin. Unlike Ward and Skaar, they measured the thermal properties at three MCs (0%, 3.6%, and 10.8%). Graphs of the specific heat are shown over a range of temperatures from -30°C to +30°C, but the equations are not provided. Of interest here is that the heat capacity results of the PF boards were about 27 percent higher than that of solid wood at oven-dry conditions. An equation determined by regression from the data given at ~25°C is shown below in a comparison table.

While the concepts of Petit and Dulong and of Debye are clearly appropriate to pure compounds and elements, it is more difficult to apply the theory to solid wood or wood-based composites that contain moisture and have varying levels of crystallinity. However, the dependence of heat capacity on temperature is clear for most materials.

Heat capacity data for plywood and OSB are nearly nonexistent, but there have been a number of measurements for solid wood heat capacity as reported in excellent review articles by Beall (1968) and TenWolde et al. (1988). Beall did a thorough review of the literature related to solid wood and correctly noted some of the problems with the results obtained from drop calorimetry, particularly the issue of the temperature. The problem occurs when a warm sample is plunged into a cold calorimeter bath and the heat capacity is calculated at a temperature between the two. The temperature issue remains a problem with most drop calorimetry measurements. As described by Beall (1968), Volbehr (1896) appears to have been the first person to report specific heat values for wood and included temperature and MC effects in his equation. Another major study of heat capacity that included North American species was by Dunlap (1912), who performed a difficult series of drop calorimeter experiments using lake ice in his cold water bath. After testing 20 species at a temperature range between 0°C and 109°C, Dunlap found that the specific heat varied about 46 percent from cold to hot, and the value at 25°C, near where the current data were taken, was about 0.292 cal/g°C. All of the data used to develop Dunlap's equation were taken with oven-dried samples, although some of his data sets show what he called the effect of steaming that increased the specific heat capacity significantly. Dunlap acknowledged a number of problems with the data collection and included a correction for the heat lost in transferring the samples from the heated oven to the calorimeter. Also, the temperatures used probably prohibited him from using anything but oven-dry wood for the tests.

TenWolde et al. (1988) summarized the work done measuring both thermal conductivity and heat capacity in solid wood and wood-based composites. After their review, they were unable to find any data related to the heat capacity of plywood and suggested using the data for solid wood as a substitute. With regard to what they termed "fiberboard" they noted only the data of Ward and Skaar (1963) and Nanassy and Szabo (1978).

The *Wood Handbook* (Forest Products Laboratory [FPL] 2010) has a brief discussion of heat capacity and lists a table of solid wood estimates at four MC values and across a range of temperatures. There is no citation for the source of

the data, but as shown below, their data probably over-predicts the heat capacity at higher MCs.

### Materials and Methods

Drop calorimetry has been used extensively to measure the heat capacity of materials (Hemminger and Höhne 1984). We used a modified version of the drop calorimetry method described by ASTM C351,<sup>1</sup> which calls for placing the sample in a tightly closed capsule, heating the capsule and sample to a uniform temperature that is higher than the water bath, and then dropping the heated capsule into a cooler water bath. The method allowed us to use sample sizes that we believed were representative of the panels rather than small samples that might be sufficient for solid wood. A diagram of our apparatus is shown in Figure 1. The sample was put into the capsule and then put into a beaker filled with warm water before placing both in a water bath at 40°C. The Dewar containing the “cool” water was a 1-liter-capacity KGW flat-bottom unit. For testing, it contained 450 g of distilled water at room temperature, which on average, was 22°C. The flat bottom allowed us to put a porous plate at the bottom of the vessel with a slowly turning magnetic stirrer underneath. No temperature increase was seen with the stirrer during initial measurements of the systems operation.

The basic equation for determining the heat capacity with a drop calorimeter is shown as Equation 3 (Hemminger and Höhne 1984). The energy lost by a warm sample is on the left and the energy gained by the calorimeter water is on the right.

$$C \times M_{\text{samp}}(T_H - T_M) = C_w \times M_W(T_M - T_C) \quad (3)$$

Equation 3 expands to Equation 4 after solving for the sample heat capacity and taking into account the water equivalent of the calorimeter and the heat capacity of the capsule holding the sample.

$$C = \frac{C_w M_W \times (T_M - T_C) + C_w E \times (T_M - T_C) - C_{\text{cap}} \times M_{\text{cap}} \times (T_H - T_M)}{M_{\text{samp}} \times (T_H - T_M)} \quad (4)$$

where

- $C$  = specific heat capacity of sample tested (cal/g°C),
- $M_W$  = mass of water in Dewar (g),
- $T_C$  = temperature of Dewar water before capsule added (°C),
- $T_M$  = mixture temperature (°C),
- $T_H$  = temperature of sample or bathwater (°C),
- $E$  = water equivalent of the system (g),
- $C_{\text{cap}}$  = specific heat of capsule (cal/g°C),
- $M_{\text{cap}}$  = mass of capsule (g),
- $M_{\text{samp}}$  = mass of sample being tested (g),
- $M_H$  = mass of warm water added from bath (g), and
- $C_w$  = heat capacity of water, assumed to be 1 cal/g°C.

In order to use Equation 4 to calculate the heat capacity of the samples, it was necessary to determine two additional

elements: the “water equivalent”,  $E$ , and the heat capacity of the capsule containing the sample,  $C_{\text{cap}}$ .

The “water equivalent” represents the heat capacity of the system including the Dewar and associated magnetic stirrer and plate (Fig. 1). The water equivalent is determined by adding a measured amount of warm water to the partially filled Dewar that is at room temperature. Equation 5 shows the approach.

$$E = \frac{M_H \times (T_H - T_M)}{(T_M - T_C)} - M_w \quad (5)$$

where  $M_H$  is the mass of warm water added from bath (g).

The capsule used to hold the samples was made following the guidelines in ASTM C351, which called for a thin brass capsule and a machined lid that screwed onto the capsule via a fine thread. The capsule measured 5.3 cm in diameter and was 3.8 cm high. When sealed it was watertight. The capsule heat capacity,  $C_{\text{cap}}$ , was calculated in the drop calorimeter using Equation 6.

$$C_{\text{cap}} = \frac{M_W \times C_w(T_M - T_C) + C_w E \times (T_M - T_C)}{M_{\text{cap}} \times (T_H - T_M)} \quad (6)$$

Developing a consistent, reliable technique required substantial effort. The final procedure was to place the capsule containing the sample into a warm water-filled beaker and then put the beaker in the water bath at 40°C (VWR Model 1157; accuracy,  $\pm 0.25^\circ\text{C}$ ) for an hour. The beaker and capsule were rapidly removed from the bath, and using tongs, the capsule was removed from the beaker, turned on its side to remove any accumulated water on the upper surface, and lowered into the calorimeter via a monofilament fishing line. The entire operation eventually took less than 5 seconds from the time the beaker/capsule was removed until the capsule and sample were in the Dewar. After establishing the technique, we verified that the system was producing reliable and consistent results using three plastic standards with known heat capacity values and with about the same heat capacity expected for the panels. The samples were made from an acrylonitrile butadiene styrene (ABS) resin, a polycarbonate, and nylon 6 that were machined to fit into the capsule.

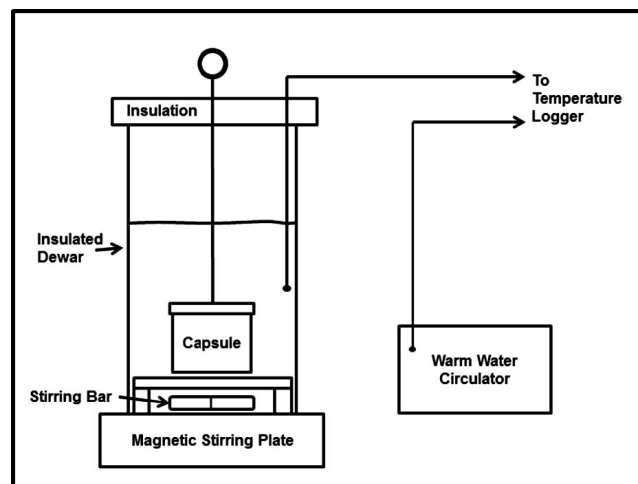


Figure 1.—Schematic of the drop calorimeter used for testing.

<sup>1</sup> ASTM C351 is now listed as “obsolete” but is still available from ASTM, 100 Barr Harbor Drive PO Box C700 West Conshohocken, PA 19428I-2959. It was used extensively for many years.

Table 1.—Geographic distribution of mills sending panels for testing.<sup>a</sup>

	South	Southeast	North	Canada
OSB	6	4	2	3
Plywood	7	1	0	0

<sup>a</sup> South includes Arizona, Georgia, Alabama, Texas, Mississippi, and Florida; Southeast includes Virginia, West Virginia, and North Carolina; north includes Maine and Minnesota; and Canada includes Manitoba, British Columbia, and Quebec. OSB = oriented strand board.

OSB and plywood sheathing samples were received from 23 mills across the United States and Canada (Table 1). Each mill sent two panels measuring 0.6 by 0.6 m by thickness. Four of the mills provided plywood that was three layers thick; the remainder had four layers. The average thickness was 11 mm. It was requested that the panels supplied be from different batches if batch processing was used at the mill. However, we do not know if the request was consistently honored.

The samples used for the tests consisted of nominally sized 50-mm-diameter disks machined from the panels. For each assessment of heat capacity, two or three disks from a panel were put into the capsule. Our target was to use three disks for each assessment, but swelling at higher MCs limited the testing to two samples. In total, 184 tests were done.

After the system was calibrated using plastic, the initial tests were done with samples at “room condition,” which averaged about 9 percent MC. The room condition samples were kept for about 7 months in a temperature-controlled room at ~22°C where the average relative humidity was ~48 percent. The samples were then conditioned at equilibrium moisture content (EMC) settings of 14.4 percent (~23°C and 75% RH) and then at 18.8 percent (~23°C and 87% RH) MC and retested before drying them at 103°C ± 2°C and performing a final test. At each EMC condition above 0, the samples were kept in a Tenney T-11 environmental chamber for a minimum of 2 months before testing. More details of the MC conditions are given below.

Both the heated bath and Dewar temperatures were carefully measured using a Hart Scientific Model 1560 “Black Stack.” The heated bath was measured with a Hart Scientific PRT model 5622-10 probe attached to a model 2562 scanner. The system is accurate to ±0.01°C, and the probe is considered “fast response.” The room temperature Dewar water was measured, before and after immersion, with a Hart Scientific model 5611T thermistor attached to a model 2564 scanner. The system is accurate to ±0.0025°C at 0°C. Both were four wire systems, and the probes were calibrated to National Institute of Standards and Technology standards and certified.

## Results and Discussion

The water equivalent,  $E$ , of the system represents the heat capacity of the calorimeter assembly and is calculated as shown in Equation 5. The value of  $E$  was 58.776 g with a standard deviation of 3.52 g. The wide value of the standard deviation was of concern, and the impact of the error in the measurement of  $E$  is not straightforward because of its position in the equation. The impact of the error was assessed in two different ways.

Table 2.—“Book” and measured values of the standards used for testing the system.

Sample	“Book” value (cal/g/°C)	Measured value (SD) (cal/g/°C)
Nylon 6 <sup>a</sup>	0.346–0.376	0.352 (0.001)
Polycarbonate <sup>b</sup>	0.28	0.271 (0.007)
ABS resin <sup>b</sup>	0.31	0.307 (0.003)

<sup>a</sup> Source: Gaur et al. (1983). Gaur et al. include the values over a range of temperatures.

<sup>b</sup> Source: Daniels (1989).

First, the impact of the variability of  $E$  on the heat capacity was assessed using a five-value average of the Nylon 6 standard without the capsule. The value of the plastic standard should be invariant, and without using the capsule it allows the removal of two variables and sources of error in Equation 4. From those data, we calculated the heat capacity using the upper and lower limits of the standard deviation, that is,  $E \pm 3.52$  g. The heat capacity of the standard varied by 0.6 percent, which affected the third decimal place in the calculation of the heat capacity. The second approach was to use the overall error in the estimate of  $C$  using the standard error of the regression estimate discussed below. After applying both methods of error assessment, it was clear that the variation in  $E$  did not have a major impact on the heat capacity.

The measured heat capacity of the capsule averaged 0.094 cal/g/°C (SD = 0.004) in line with established heat capacity values for the brass that was used to construct the capsule (Oberg et al. 1996). The results of measuring the three plastic standards and their comparison to “book” values are shown in Table 2. After repeated testing, we felt the method accurately predicted the value of the specific heat of the plastics as reported by others. During the actual testing, the average mix temperature of the calorimeter after adding the heated capsule and sample was 22.894°C.

Summary data for all of the heat capacity measurements are shown in Table 3, and the general findings are about the same as for solid wood. Although the heat capacity data on wood-based composites is scant, it is likely that a composite made largely from wood has a heat capacity similar to a solid wood sample. When compared with the data of Dunlap (1912), Ward and Skaar (1963), Nanassy and Szabo (1978), American Society of Heating, Refrigerating and Air-Conditioning Engineers (2001), and the *Wood Handbook* (FPL 2010), the heat capacity reported here is nearly identical at a

Table 3.—Summary data for all samples tested.<sup>a</sup>

Composite	Nominal MC (%)	Actual MC (%)	CV (%)	$C$ (cal/g/°C)	CV (%)
OSB ( $n = 30$ )	Dry	0	0	0.274	4.44
	“Room”	8.51	11.17	0.334	2.99
	14.4	12.54	4.61	0.370	1.97
	18.8	16.63	4.01	0.367	3.33
Plywood ( $n = 16$ )	Dry	0	0	0.266	5.63
	“Room”	9.41	6.87	0.340	2.93
	14.4	13.29	4.24	0.373	1.49
	18.8	17.91	4.38	0.381	2.88

<sup>a</sup> The nominal moisture content (MC) is for the chamber equilibrium moisture content and “Room” is as received. CV = coefficient of variation;  $C$  = heat capacity.

Table 4.—Comparison of the various values of solid wood and wood-based composite heat capacity found in the literature.<sup>a</sup>

Source	Material	MC (%)	T (°C)	C (cal/g°C)	Equation/source
Volbehr (1896) <sup>b</sup>	Solid wood	12	22	0.284	$C_p = 0.259 + 0.000975 + 0.000605T_1 + 0.00015MC_1T_1$
Dunlap (1912)	Solid wood	0	22	0.292	$C = 0.266 + 0.00166T$
Wood Handbook (FPL 2010) <sup>c</sup>	Solid wood	12	22	0.386	$C = 0.2606 + 0.001307T + 0.008057MC$
This study	OSB	12	22	0.354	$C = 0.2796 + 0.006MC$
This study	Plywood	12	22	0.352	$C = 0.2719 + 0.0067MC$
Ward and Skaar (1963)	Waferboard	8.3	22	0.354	$C = 0.310 + 0.002T$
Nanassy and Szabo (1978) <sup>c</sup>	PF waferboard	12	25	0.345	$C = 0.330 + 0.00123MC$
ASHRAE (2001)	Plywood	NA	NA	0.29	ASHRAE F, 25.4 Table 4, Douglas-fir

<sup>a</sup> MC = moisture content, dry basis; T = temperature; C = heat capacity;  $C_p$  = constant pressure;  $T_1$  = final temperature (°C); FPL = Forest Products Laboratory; OSB = oriented strand board; PF = phenol-formaldehyde; ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers; NA = not applicable.

<sup>b</sup> Equation as reported by Beall (1968).

<sup>c</sup> Regression of data from paper/document.

temperature of about 22°C. Table 4 is a comparison of values obtained or calculated from the data given in the cited literature and measured during these experiments.

Graphs of all data are shown in Figure 2 for both the OSB and plywood, and the equations from the regressions are shown in Table 4. An *F* test comparing the slopes for the data sets produced a *P* value of 0.9726, indicating that there was no significant difference in the slopes. Equation 7 is for the combined OSB and plywood data, and the standard error of the estimate of 184 observations was 0.014, which incorporates all sources of measurement error as well as the variation in the sample. A plot of the residuals showed no distinct pattern indicating that a linear fit was appropriate for the data set

$$C = 0.277 + 0.0063MC \quad (7)$$

Equation 8 can be used to approximate the effect of MC on the heat capacity using the rule of mixtures (Skaar 1988). The method is similar to that used by TenWolde et al. (1988) for solid wood heat capacity, although Skaar does not include an adjustment term for the wood water bond at low MC values. The expected heat capacity using Equation 8 was calculated using the mean values of both

the MC and heat capacity from Table 3. The results are shown in Table 5.

$$c_m = \frac{c_0 + mc_w}{1 + m} \quad (8)$$

where

$c_m$  = heat capacity of moist wood,

$c_0$  = heat capacity of dry wood,

$c_w$  = heat capacity of water, and

$m$  = mass of moisture per unit dry mass of wood.

The rule of mixtures approach assumes that the only factor affecting heat capacity is MC and is further biased by including only the average heat capacity measured at 0 percent. Clearly the values of both the predicted and measured heat capacities are closely matched, suggesting that the dry basis MC is the dominant factor in the increase of the heat capacity, as expected. A comparison of the rule of mixtures linear fit compared with a linear regression fit for the OSB and plywood data is shown in Figure 2.

For the OSB, only a few of the manufacturers provided the species mix or the hardwood/softwood proportions used in the panels. For the plywood, all were southern pine, with

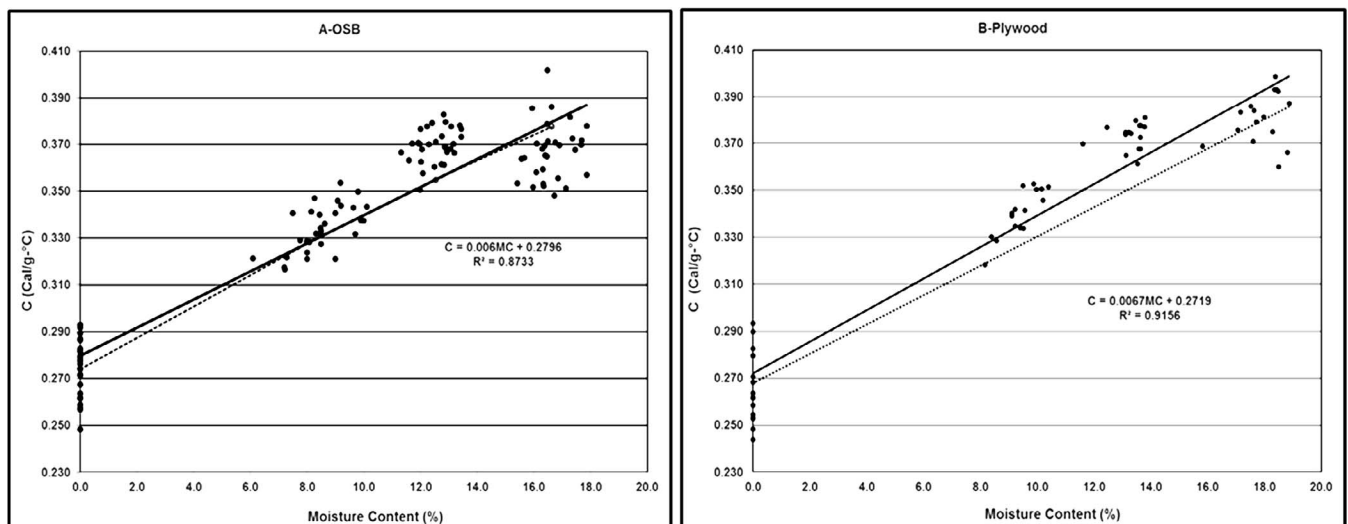


Figure 2.—Heat capacity for (A) oriented strand board (OSB) and (B) plywood. The solid lines are linear regression fits of the actual data as shown by the equations in the figure. The dashed lines show the linear fit based on Equation 8, the rule of mixtures.

Table 5.—Mean values of moisture content (MC) and measured heat capacity (C) as well as the rule of mixtures predicted heat capacity.<sup>a</sup>

	Mean MC (%)	C (cal/g/°C)	
		Mean	Prediction
OSB	Dry	0.27	0.27
	8.51	0.33	0.33
	12.54	0.37	0.35
	16.63	0.37	0.38
Plywood	Dry	0.27	0.27
	9.41	0.34	0.33
	13.29	0.37	0.36
	17.91	0.38	0.38

<sup>a</sup> The measured values are from Table 3. The predicted values are from Equation 8.

one exception where hardwood was used. There were enough data to compare regional differences for the panels after the OSB and plywood data sets were combined. Summary data for heat capacity, by region, and the range of dry density values are shown in Table 6. An analysis of variance (ANOVA) comparing the heat capacity values from each region and at each MC showed an interesting result. At low MCs (dry and 8.8% average MC), there was no significant difference in the heat capacity values among the regions (*P* value in Table 6). As the MC increased, the standard deviation decreased among the regional values, and the ANOVA showed significantly different heat capacity values as measured by the *P* value (Table 6).

The overall slopes of the OSB and plywood curves have already been discussed, but there were also interesting findings when the data for both OSB and plywood were analyzed separately. When the heat capacity values at each MC level were compared statistically using a *t* test, the OSB and plywood in the dry condition showed that the data were not significantly different (*P* value = 0.104), but when the data were compared at the “room” condition and at nominal values of 14.4 and 18.8 percent MC, the data were significantly different (*P* values of 0.002, 0.015, and 0.005, respectively). Although the samples were held under the same conditions for an extended period of time, they did not equilibrate to the same MC, which may be related to either the adhesive content or pressing conditions, which are known to have a permanent effect on hygroscopicity. Also, the combined equation (Eq. 8) predicts a heat capacity of 0.277 cal/g/°C at 22°C for dry samples. Remarkably, Volbehr’s equation (1896) for solid wood predicts 0.273 for the same conditions (Table 4).

Table 6.—Regional comparison of all heat capacity data.<sup>a</sup>

Region	Dry density, range (kg/m <sup>3</sup> )	<i>n</i>	C (cal/g/°C) at avg. MCs of:			
			Dry	8.8%	14.4%	18.8%
South	507.5–764.3	26	0.285	0.353	0.391	0.396
Southeast	547.5–687.3	10	0.306	0.371	0.395	0.402
North	548.7–724.7	4	0.319	0.370	0.402	0.408
Canada	536.5–716.5	6	0.319	0.363	0.405	0.411
<i>P</i> value			0.001	0.025	0.219	0.204

<sup>a</sup> All standard deviation values are 0.03 or less. *C* = heat capacity; MC = moisture content.

## Conclusions

It is clear that the heat capacity of wood composite sheathing is affected by MC in a significant way. During these tests, the heat capacity changed by about 18 percent in the range between 6 and 15 percent MC. The change in values will demonstrably affect the thermal mass of a wall and should be considered when modeling wall systems. It is also apparent that in over 100 years of testing, all of the credible measurements of wood-based heat capacity fall within the range 0.25 to 0.4 cal/g/°C. While the range appears to be narrow, using the correct value for hygrothermal models can make a significant difference in the energy efficiency of a structure.

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