SHRINKAGE OF OUTERWOOD, MIDDLEWOOD, AND COREWOOD OF TWO SWEETGUM TREES[1]

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ABSTRACT

Two sweetgum (*Liquidambar styraciflua* L.) trees were used to determine the shrinkage properties of green outerwood, middlewood, and corewood. Samples were taken at various heights along the boles from each side of a disk. Shrinkage displayed the following general pattern: corewood > middlewood > outerwood. This pattern was reversed for the specific gravity of samples from each of these wood types from tree 1, but tree 2 maintained a relatively uniform specific gravity among wood types.

Keywords: Moisture content, shrinkage, specific gravity, sweetgum.

Sweetgum (*Liquidambar styraciflua* L.) is one of the most widespread trees in the southern forest. It commonly is associated in natural stands with baldcypress (*Taxodium distichum* L.), tupelo (*Nyssa* spp. L.), and the southern pines (*Pinus* spp.) (Harlow et al. 1979). Sweetgum, which has a green specific gravity (SG) of 0.46 (USDA Forest Products Laboratory 1987) is one of the more important commercial hardwood species of the United States. In particular, it is the most important species in the United States for hardwood veneer production. Also, it is increasingly favored by the southern paper industry, but it is of limited lumber value because of its poor tree form and tendency to form interlocked grain (Panshin and de Zeeuw 1980).

The kiln-drying of sweetgum is an important step for a variety of subsequent end-uses. A major problem in using hardwoods for structural and other small-dimension lumber is warp (Maeglin et al. 1985); therefore, it is necessary to remove moisture in the wood at a rate that minimizes the development of drying defects and stresses. Production demands often require a rapid drying schedule that allows for

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maximum turnover with minimum loss of grade. It is therefore important for processors to understand the drying behavior of sweetgum lumber if they are to achieve efficient utilization of the resource.

Previous research by James et al. (1984) on kiln-drying of commercial softwood lumber found substantial variation in the average moisture content (MC) between boards, within boards, and from mill to mill. Choong and Fogg (1989) postulated that the initial MC of wood prior to drying is one of the many factors that contribute to such large variation. The initial MC of wood often is quite variable because of the difference in MC between heartwood and sapwood. Therefore, boards comprised of varying percentages of heartwood and sapwood will display a wide range of initial MCs.

Research by Shupe et al. (1995a) has found statistically significant differences among shrinkages of outerwood, middlewood, and corewood wood types for yellow-poplar. Shrinkage and specific gravity displayed the following pattern: outerwood > middlewood > corewood. A study by Shupe et al. (1995b) on eastern cottonwood showed the same trend with outerwood and innerwood. Choong et al. (1989) have also found significant variation in volumetric shrinkage of different wood types of second-growth baldcypress and tupelo-gum, but they reported the following trend for volumetric shrinkage and specific gravity: innerwood > middlewood > outerwood. It is clear that wood type is a significant factor that should be addressed to understand the shrinkage of wood.

For sweetgum, it is likely that wood density (green SG = 0.46) and the difference in heartwood MC (79%) and sapwood MC (137%) are critical factors in explaining its shrinkage behavior (5.3% radially, 10.2% tangentially, and 15.8% volumetrically) (USDA Forest Products Laboratory 1987.) Therefore, the objective of this study was to investigate the variability of shrinkage and specific gravity within each wood type of two sweetgum trees dried from an initial green condition.

MATERIALS AND METHODS

Two defect-free, codominant sweetgum trees approximately 40 years of age were felled in the winter on a bottomland site along the Mississippi river near Baton Rouge, LA. Each tree was 35.5 cm in diameter at breast height (dbh) and 24.6 m in total height. A total of 15 disks, approximately 25.4 mm thick, were removed from each tree starting at ground level and progressing upward along the bole at increments of 1.0 m to a tree height of 18.7 m.

At the laboratory, a 25.4-mm-wide strip oriented in the north-south direction was removed from each disk. The center of each strip contained the pith of the disk. Samples measuring 25.4 mm tangentially, 12.7 mm radially, and 12.7 mm longitudinally were removed from each strip and categorized into one of three wood types: outerwood, middlewood, and corewood. Outerwood samples were removed from the sapwood region, and middlewood was considered to be in the outer heartwood region. Corewood was treated as the inner core, approximately the inner half of the heartwood area. Samples from the north and south halves (quadrants) were isolated in order to determine the effect of quadrant on shrinkage. In the statistical analysis, the term *All* is simply the pooled observations of all three wood types.

Green specimens were conditioned in an Aminco environmental chamber at 38 C and 70% relative humidity (RH) until equilibrium moisture content (EMC) was achieved. Samples were conditioned to a nominal 70% RH using a dial gauge connected to the Aminco chamber. Specimen weights and dimensions were determined, and then specimens were oven-dried at 101 C for 24 h. Specimens were weighed and measured again to determine the shrinkage and hygroscopic properties of green wood.

Specific gravity (SG), based on green volume and oven-dry weight, was determined by the maximum MC method (Smith 1954) for all specimens before any further experimentation. All shrinkage values were determined from the ratio of change in dimension from the swollen

TABLE 1. *Analysis of variance of sweetgum wood dried from an initial green condition.*

Source	df	Green MC[1] (%)				EMC[2] (38 C and 70% RH[3])				Radial shrinkage (S_R)				Tangential shrinkage (S_T)				Specific gravity (SG)			
		All[4]	OW[5]	MW[6]	CW[7]	All	OW	MW	CW	All	OW	MW	CW	All	OW	MW	CW	All	OW	MW	CW
Tree	1	**	NS	NS	**	**	NS	NS	NS	**	NS	*	**	**	NS	**	*	NS	NS	NS	**
Quad. (Q)[8]	1	**	NS	*	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ht. (H)[9]	14	**	NS	*	*	**	NS	NS	**	NS	NS	NS	NS	**	NS	NS	**	**	NS	*	*
Q × H	14	**	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not statistically significant at $\alpha = 0.05$.
** Significant at $\alpha = 0.05$.
* Significant at $\alpha = 0.01$.
[1] Green moisture content (%).
[2] Equilibrium moisture content (%).
[3] Relative humidity (RH) (%).
[4] All wood types combined.
[5] Outerwood.
[6] Middlewood.
[7] Corewood.
[8] Quadrant (north or south).
[9] Height.

condition to oven-dry condition to swollen dimension, expressed as a percentage. Volumetric shrinkage was estimated from the summation of radial and tangential shrinkage, which has been shown to give a relatively close approximation of the true volumetric shrinkage (Choong 1969). The linear dimensions were measured at room temperature with a digital caliper to the nearest 0.001 mm.

Data were analyzed using analysis of variance, *t*-tests, and simple linear regression techniques (Steel and Torrie 1980) in accordance with SAS programming methods (SAS 1989).

RESULTS AND DISCUSSION

The analysis of variance (AOV) for green MC (Table 1) revealed that many sources of variation (SOV) were significant. The data for all wood types combined (All) was significant for all SOV. In outerwood, green MC failed to differ significantly for any SOV in spite of the fact that outerwood showed the greatest difference in mean green MC between the two trees. Tree 1 displayed an outerwood mean green MC of 113.6%, and tree 2 was 130.7% (Table 2). Middlewood MC was not significantly different among trees, but was significantly different for all other SOV (Table 1). The mean green MCs of middlewood for trees 1 and 2 were 125.5% and 128.1%, respectively (Table 2). These values are higher than those reported by Henderson and Choong (1968), who found the mean January MC of sweetgum to range from 95.6%–100.0% across three Louisiana sites. The quadrant × height interaction was the only nonsignificant SOV for corewood.

Equilibrium moisture content at 38 C and 70% RH did not differ significantly for any SOV, except among heights in the corewood and among trees and heights for all wood types combined. The predicted EMC for a dry-bulb temperature of 38 C and 70% RH is 12.3% (USDA Forest Products Laboratory 1987). This study found the EMC to range from 12.0%–13.3% at these nominal conditions. Both radial and tangential shrinkage differed significantly among trees for middlewood, corewood, and all wood types combined. Tan-

TABLE 2. *Summary of mean values of selected wood properties of two sweetgum trees for specified wood types.*

Measured property	Tree 1	Tree 2
	Outerwood (sapwood)	
No. of samples	38	38
Green MC (%)	113.6 (17.3)[1]	130.7 (16.7)
EMC at 38 C and 70% RH (%)	13.0 (0.5)	12.0 (0.5)
Radial shrinkage (S_R) (%)	5.9 (0.5)	5.1 (0.4)
Tangential shrinkage (S_T) (%)	8.8 (0.7)	9.7 (0.9)
S_T/S_R ratio	1.5 (0.2)	1.9 (0.3)
SG (green volume)	0.50 (0.04)	0.47 (0.03)
	Middlewood (heartwood)	
No. of samples	43	50
Green MC (%)	125.5 (24.4)	128.1 (14.2)
EMC at 38 C and 70% RH (%)	13.0 (0.6)	13.0 (0.3)
Radial shrinkage (S_R) (%)	5.9 (0.9)	5.3 (1.2)
Tangential shrinkage (S_T) (%)	9.0 (0.8)	10.3 (0.6)
S_T/S_R ratio	1.6 (0.2)	2.1 (0.9)
SG (green volume)	0.48 (0.05)	0.48 (0.03)
	Corewood	
No. of samples	30	17
Green MC (%)	117.9 (18.0)	126.5 (17.0)
EMC at 38 C and 70% RH (%)	13.3 (0.5)	13.1 (0.5)
Radial shrinkage (S_R) (%)	7.0 (0.8)	7.6 (0.5)
Tangential shrinkage (S_T) (%)	10.5 (1.9)	11.6 (1.2)
S_T/S_R ratio	1.5 (0.3)	1.6 (0.4)
SG (green volume)	0.46 (0.03)	0.47 (0.03)

[1] Numbers in parentheses are standard deviations.

gential shrinkage differed significantly among heights for corewood and all wood types combined. Specific gravity differed significantly among trees for corewood and among heights for middlewood, corewood, and all wood types combined.

The SOV that showed the most significant differences for the wood types within each measured property were the tree and height factors. In fact, at least one wood type showed a significant difference between trees for all five properties measured (Table 1). Similarly, at least one wood type differed significantly among heights for all properties except radial shrink-

TABLE 3. *Correlations between wood characteristics of sweetgum wood dried from an initial green condition.*

	Correlation ($P < 0.01$)								
	Outerwood		Middlewood		Corewood		Combined[1]		All[2]
Relationship	Tree 1	Tree 2	Tree 1	Tree 2	Tree 1	Tree 2	Tree 1	Tree 2	
MC vs. SG	NS	−0.38*	NS	NS	NS	NS	NS	NS	NS
Vol shr.[3] vs. SG	0.41**	NS	NS	NS	NS	NS	NS	NS	NS
MC vs. height	−0.51**	−0.42**	NS	NS	NS	NS	−0.34**	−0.36**	−0.32**
SG vs. height	NS	0.66**	NS	NS	0.44*	NS	0.30*	0.44**	0.36**
Vol. shr. vs. height	−0.39*	NS	NS	NS	−0.42**	NS	−0.40**	−0.43**	−0.42**

NS = Not statistically significant at $\alpha = 0.01$.
** Significant at $\alpha = 0.05$.
* Significant at $\alpha = 0.01$.
[1] All wood types combined.
[2] All wood types and trees combined.
[3] Vol. shr. = summation of radial and tangential shrinkages.

age. Table 3 shows there were weak correlations for MC, SG, and volumetric shrinkage versus heights in never-dried wood for all wood types combined.

It is typical for shrinkage patterns of specific wood types to parallel the natural variation of tree density from pith to bark and along the bole. However, the correlation between calculated volumetric shrinkage, summation of radial and tangential shrinkages, and SG was only slightly significant for outerwood of tree 1 (Table 3). The correlation between calculated volumetric shrinkage and SG was not significant for any wood types for tree 2. Our study found that SG of middlewood, corewood and all wood types combined differed significantly among heights in the AOV (Table 1) but were weakly and inconsistently correlated (Table 3).

SUMMARY

Samples were obtained from two sweetgum trees to determine the effect of wood type, height, and quadrant (north and south) on shrinkage of green wood. Results indicate a decrease in shrinkage with increasing distance from the pith (i.e., corewood > middlewood > outerwood). Specific gravity increased with increasing distance from the pith (i.e., outerwood > middlewood > corewood) for tree 1, but remained relatively uniform for tree 2.

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