Properties of wood from ice-storm damaged loblolly pine trees

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Abstract

Fifty-six trees were harvested to determine the properties of the wood produced by ice-storm damaged trees. There were 12 trees each for three classes of bend: 0 to 15, 16 to 30, and more than 30 degrees from the vertical. Also, 10 trees were selected for each of two classes of crown loss: 20 percent or less and more than 20 percent loss. Samples were taken from three positions in the tree: butt, 8 feet up the stem and at the base of the live crown. The variables analyzed were: the amount of compression wood produced, ovendry specific gravity (SG), modulus of rupture, and modulus of elasticity (MOE). The results indicated that the greater the degree of bend, the more compression wood produced, the higher the SG and the lower the MOE. It was recommended that trees with just a partial loss of crown be allowed to grow, but trees with more than 15 to 20 degrees of bend should be harvested.

During the Christmas Holiday period of 2000, South Arkansas experienced a devastating ice storm. Larger trees suffered minimal crown damage in the form of broken limbs or lost tops. In contrast, plantations of younger trees were severely damaged. Based on visual observations, it appeared that stands that had been thinned recently were hit the hardest.

Shortly after the ice storm, the U.S. Forest Service (USFS) initiated a study of nearly 300 trees in six loblolly pine plantations. In selected plantations, USFS personnel selected and marked trees that were leaning (root thrown), bent, and exhibiting crown loss. During each of the following five dormant seasons, data were collected on the marked trees. After five growing seasons, the trees were divided into three groups. The first group died within 2 years of the ice storm. The second group were surviving but had no measurable diameter growth in the 5 years. The third group had measurable diameter growth each year. From a monetary prospective, the first two groups should have been harvested following the ice storm. The purpose of this study was to evaluate the properties of the third group in an effort to determine if the material produced by the trees was worth growing. It should be noted that all of the leaning trees were in group one. Given this fact, the study included only trees that were bent and those with some degree of crown loss. The information derived from this study should aid forest managers in harvest and clean up decisions following future events such as ice storms.

When softwood trees are bent, future growth results in compression wood being formed on the lower side of the stem. This response is the tree's way of forcing the stem back into a vertical position. This abnormal wood has properties that are different and less desirable than normal wood. Considerable care must be used in pulping compression wood, and even then an inferior product is produced. With solid products such as lumber, differential shrinkage is of great concern. Density of compression wood is 10 to 20 percent higher and sometimes as much as 40 percent higher than normal wood, but its strength is about the same as normal wood (Bowyer et al. 2003).

The amount of bending, rather than the reason behind it, seems to be the only important factor in the amount of compression wood that is produced. Clark and Dunham (2001) studied bent trees 10 years after Hurricane Hugo and investigated the influence of the amount of bend and age at the time of Hugo on the properties of the resulting wood. Their conclusions were:

- Angle of lean did not significantly affect stem wood specific gravity (SG) or moisture content (MC).

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*Forest Products Society Member.

Forest Prod. J. 57(12):48-51.

- Average compression wood SG was about 2 percent higher than normal wood.
- Compression wood toughness was 21 percent lower than normal wood.
- Proportion of stem in compression wood increased significantly with increasing tree age at time of storm in tree with >25 degrees of lean.
- Trees of age 4 years or less with 45 degrees of lean or more and trees of 8 years with 25 degrees of lean or more, should be harvested and replanted because of the large amount of compression wood that would be produced.

In this study the modulus of elasticity (MOE) and modulus of rupture (MOR) were used to compare the mechanical properties of the wood. American Society for Testing and Materials (ASTM) (ASTM-D143 2005) provides a standard for determining MOE and MOR based on testing of sample beams that are 2 inches by 2 inches and tested over a 28-inch span. The standard also provides an alternative size (method b) of 1 inch by 1 inch over a 14-inch span which is used when the material to be studied cannot be processed into larger size (McAlister and Clark 1991, McAlister and Powers 1992, McAlister and Powers 1994). Others have found that the alternative size (method b) is still too large for many studies. Therefore, smaller specimens have been used but the span to depth ratio has always been maintained at 14 to 1. The extreme case is an 1/8-inch beam tested over a 1 3/4-inch span (Bendtsen and Senft 1986, Wolcott et al. 1986, Shepard and Shottafer 1992).

Procedures

The group three trees were divided into five classes: class one trees were those bent 0 to 15 degrees from the vertical, class two trees were bent 16 to 30 degrees, class three trees were bent more than 30 degrees, class four trees had up to 20 percent crown loss and class five trees had more than 20 percent crown loss. The top 12 trees in diameter growth since the storm were selected for each of the first three classes and the top 10 were selected for classes four and five. Thus, samples from 56 trees were included in this study.

The trees were harvested during June 2006, which was the middle of the sixth growing season. Prior to felling, a paint line was sprayed up the upper side of the tree so that the upper and lower side of the stem could be identified after felling. The trees were felled with a chain saw leaving a 6-inch stump. A 1-inch-thick cross section was removed from the main stem at the base of the live crown (top position) and placed in a preweighed plastic zip lock bag. An 18-inch-long segment was cut from the stem below the cross section. Next a 1-inch cross section was cut at 8 feet from the butt end of the stem (mid position), placed in a plastic bag, and an 18-inch segment was cut above it. Finally, from the butt end, a 1-inch cross section and an 18-inch segment were cut (butt position). The harvested materials were taken to the lab each afternoon. The cross sections and bags were weighed, and the wood was placed in the oven to dry for MC determination. The 18-inch segments were stacked for later processing.

The cross sections were reweighed after drying and placed back in their respective plastic bags. Later, they were analyzed for growth patterns. Digital calipers were used to measure the width of the last six growth rings on both the upper and the lower side of the stem. Also, the width of any compression wood present was measured for each growth ring since the ice storm.

Table 1. — The difference in inches between the lower side 6-year growth minus the upper side 6-year growth by study class. Values in same position with the same letter are not significantly different.

	Position		
Class	butt	mid	top
1	0.1871ab	0.0967b	0.0724b
2	0.2948ab	0.2259b	0.2315ab
3	0.4471a	0.5661a	0.2920a
4	0.1163b	0.0126b	0.1540ab
5	0.0779b	0.0316b	0.1797ab

Classes: 1 = 0 to 15 degrees; 2 = 16 to 30 degrees; 3 = >30 degrees; 4 = 0 to 20 percent crown loss; and 5 = >20 percent crown loss.

The 18-inch segments were positioned on a portable sawmill so that the blade would pass parallel to the bark and remove only the last six growth rings. This cut was done for both the upper and lower sides of the stem. The segment slabs were further processed on a table saw to produce the largest beam possible based on the width of the growth rings. When the bark side was removed from the beam, the sixth growth ring and possibly some of the fifth growth ring were lost; therefore the static bending beams consisted of only the first five growth rings after the ice storm. The 336 beams were kiln-dried and then placed in a conditioning chamber.

The beams were tested according to ASTM standards (2005) except for size. There were four sizes of beams: 1-inch over a 14-inch span, 3/4-inch over a 10 1/2-inch span, 5/8-inch over an 8 3/4-inch span and 1/2-inch over a 7-inch span. After failure, an end was cut from each beam for MC and oven dry SG determination.

SAS® (2003) was used in all statistical analyses involving t-tests and ANOVA and a p-value of 0.05 was used to determine significance.

Results and discussion

For wood from the same position of the trees, there was no significant difference in MC between the classes or plantation sites. However, there was a significant difference in MC by position. The study averages were 91, 96, and 116 percent for the butt, mid and top positions, respectively. This is similar to the relationship of MC to position shown in Patterson and Doruska (2005).

When trees produce compression wood, the growth rings on the upper side of the stem are usually narrow while the same growth rings on the lower side are usually wider. **Table 1** shows the difference in width between the last six growth rings on the lower side and those on the upper side. The variation in the data prevents any identification of a statistical trend; although, trees with more than 30 degrees of bend had the highest average for all three positions. It is noted that in some processes, such as veneer production, out-of-round logs make it difficult for plywood plants to peel quality veneer even if there is clear material outside the compression wood because the knife is cutting across growth rings instead of around them.

Some trees in all three classes of bent trees were producing compression wood in the mid position during the fourth year after the ice storm and some in class 3 were still producing compression wood in the sixth year (**Table 2**). The mid position is 8 feet from the stump which places it in the middle of

Table 2. — The average amount of compression wood in inches laid down each year since ice storm by study class and position.

		Year					
Class	Position	1	2	3	4	5	6
1	butt	0	0	0	0	0	0
	mid	0.103	0.017	0.024	0.015	0	0
	top	0.105	0.013	0	0	0	0
2	butt	0.067	0.005	0.021	0.018	0	0
	mid	0.272	0.009	0.026	0.029	0	0
	top	0.210	0.016	0.015	0.015	0.004	0
3	butt	0.211	0.093	0.031	0.014	0.006	0
	mid	0.267	0.132	0.123	0.086	0.050	0.019
	top	0.191	0.093	0.051	0.039	0.008	0.003
4	butt	0.021	0.008	0.012	0	0	0
	mid	0	0	0	0	0	0
	top	0	0	0	0	0	0
5	butt	0	0	0	0	0	0
	mid	0	0	0	0	0	0
	top	0.018	0.012	0.017	0	0	0

Classes: 1 = 0 to 15 degrees; 2 = 16 to 30 degrees; 3 = >30 degrees; 4 = 0 to 20 percent crown loss; and 5 = >20 percent crown loss.

*Table 3. — Average SG values for the lower side and upper side for each position and study class. The ** denotes significant difference in lower side value compared to upper side value.*

	Position					
	butt		mid		top	
Class	lower	upper	lower	upper	lower	upper
1	0.601	0.624	0.579	0.574	0.487	0.461
2	0.646	0.648	0.621	0.619	**0.527	0.483
3	0.645	0.634	**0.655	0.597	**0.596	0.462
4	0.636	0.625	0.558	0.558	0.453	0.448
5	0.587	0.586	0.548	0.548	0.443	0.428

Classes: 1 = 0 to 15 degrees; 2 = 16 to 30 degrees; 3 = >30 degrees; 4 = 0 to 20 percent crown loss; and 5 = >20 percent crown loss.

*Table 4. — Average MOR values (x1,000 PSI) for the lower side and upper side test specimens for each position and study class. The ** denotes a significant higher value as compared to its opposite side.*

	Position					
	butt		mid		top	
Class	lower	upper	lower	upper	lower	upper
1	11.6	**12.5	14.0	13.4	11.9	10.7
2	11.9	13.2	13.6	14.6	11.1	10.6
3	11.7	13.0	11.6	12.5	11.4	10.3
4	**13.1	11.8	12.8	13.3	10.7	9.9
5	12.2	11.5	11.7	13.7	10.3	9.8

Classes: 1 = 0 to 15 degrees; 2 = 16 to 30 degrees; 3 = >30 degrees; 4 = 0 to 20 percent crown loss; and 5 = >20 percent crown loss.

the butt log. The butt log is the "money" log of the tree and anything that degrades the butt log may greatly reduce the value of the whole tree. Even though it is the same growth ring, there appears to be less compression wood produced at the base and the crown area than in the main stem.

Bowyer et al. (2003) stated that compression wood generally has a SG that is 10 to 20 percent and as much as 40 percent higher than normal wood. The data analysis showed that there were significant differences in ovendry SG values for the mid position in class 3 trees and top position in classes 2 and 3 trees (**Table 3**). In these three cases, the lower side SG values were 9 to 29 percent higher than those from the opposite side of the tree. The values in **Table 3** basically correspond to the amount of compression wood shown in **Table 2**.

The analysis indicated no significant trends in MOR values. **Table 4** shows two cases where there were significant differences; in one case the upper side of the butt position had the higher MOR value while in the other case the lower side was higher. These results are in agreement with a statement by Bowyer et al. (2003) stated that compression wood had the same strength as normal wood even though it was heavier.

MOE is a measure of stiffness, and the results of this study would indicate that compression wood is less stiff than normal wood. The values in **Table 5** show that the upper side had a higher average MOE than the lower side with the exception of the butt position of class 4 trees in which the lower side was stronger and stiffer. There were five cases where the upper side had significantly higher MOE values. The extreme case was the mid position of class 3 trees where the lower side was only 60 percent as stiff as the upper side even though it had a 29 percent higher SG. The beams containing predominately compression wood had the same strength as their opposite side counterparts, but because of their lack of stiffness, with a constant loading rate, the test to the maximum strength required a long time period and great deflection of these beams.

The MC at the time of testing was 14 percent instead of 12 percent as planned. It appears that the calibration of the conditioning chamber was a little off. Given the comparative nature of the study, values were not corrected to 12 percent.

Conclusions

The results of this study demonstrate that ice storm damaged trees can be adversely affected (e.g., reduction in MOE) even if they survive and produce diameter growth. Some senior foresters working in the study area stated that in the 1970s there was a severe ice storm, and their instructions at that time

*Table 5. — Average MOE values (x 1,000,000 PSI) for the lower side and upper side test specimens for each position and study class. The ** denotes a significant higher value as compared to its opposite side.*

	Position					
	butt		mid		top	
Class	lower	upper	lower	upper	lower	upper
1	0.878	**0.984	1.422	1.441	1.186	1.189
2	0.849	0.931	1.138	**1.576	1.060	1.158
3	0.683	**0.949	.777	**1.294	0.838	**1.146
4	**1.157	0.997	1.326	1.453	1.099	1.136
5	0.887	0.942	1.287	1.473	1.088	1.135

Classes: 1 = 0 to 15 degrees; 2 = 16 to 30 degrees; 3 = >30 degrees; 4 = 0 to 20 percent crown loss; and 5 = >20 percent crown loss.

were to ask two questions. First, is the tree straight? Second, are there three or more limbs? If the answer to either question was no, the tree was to be harvested.

The study results indicated that the loss of part of the crown did not cause compression wood to be produced in the main part of the stem. Therefore, the partial loss of crown did not cause a reduction in quality of future growth, but there may be a reduction in the amount of growth.

Clark and Dunham (2001) recommended that trees 8 years or older should be harvested if the amount of bend is greater than 25 degrees. The results of this study indicate that if the amount of bend is over 15 to 20 degrees from the vertical, they should be harvested.

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