Comparison of Wood Utility Crossarm Properties from 1995 and 2015

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Abstract

In response to changes in forest management and conversion practices, concern has arisen that some solid wood products manufactured today exhibit decreased strength and stiffness properties (modulus of rupture [MOR] and modulus of elasticity [MOE]) compared with those manufactured in the past. This study addresses those concerns by comparing the mechanical properties of wood utility crossarms sampled in 2015 with those of a similar sample of crossarms from 1995. Destructive bending tests were performed on crossarm samples of southern pine (*Pinus* spp.) and Douglas-fir (*Pseudotsuga menziesii*). These data were compared with data from a similar 1995 study by H. M. Barnes and J. E. Winandy (pp. 30–38, *in* Proc. 97th Annu. Meet. AWPA, 2001). The results showed a statistically significant difference (7.1% reduction) at the $\alpha = 0.01$ level of mean MOR in southern pine and a statistically significant difference (13.3% reduction) at the $\alpha = 0.01$ level of mean MOE in Douglas-fir. Distribution analyses also suggested a reduction of strength performance in the lower percentiles for both species groups between the two studies.

Wood utility crossarms provide an efficient economical, structural, and sustainable solution to the distribution and transmission of electric and communication utilities. The majority of crossarms in the United States are made from two species groups, Douglas-fir (*Pseudotsuga menziesii*) and southern pine (*Pinus* spp.). The southern pine group consists of loblolly (*Pinus taeda*), longleaf (*Pinus palustris*), shortleaf (*Pinus echinata*), and slash (*Pinus elliottii*).

In response to changes in forest management and conversion practices, concern has arisen that some solid wood products manufactured today exhibit decreased strength and stiffness properties (modulus of rupture [MOR] and modulus of elasticity [MOE]) compared with those manufactured in the past. For example, softwood structural commodity lumber throughout North America has recently undergone a reexamination of mechanical properties. In their study of the bending properties of crossarms sampled in 1995, Barnes and Winandy (2001) pointed out that such concerns may come in part from the fact that trees processed today tend to be smaller in diameter than those originally tested years ago. As such, the crossarms manufactured from the smaller trees have a greater prevalence of juvenile wood. Since Barnes and Winandy published their findings, similar sentiments have only increased.

The purpose of this study was to compare the mechanical performance of solid-sawn wood crossarms manufactured and tested circa 2015 with that of the 1995 materials used in Barnes and Winandy's (2001) study. In this manner, researchers can begin to determine if properties are consistent through time.

Materials and Methods

Materials and sampling

For the 2015 study, Douglas-fir and southern pine crossarms were selected from mill run stock and graded at two different wholesale manufacturers, one in Louisiana and the other in South Carolina. All specimens included in the test were on-grade per American National Standards Institute (ANSI) O5.3-2015 (ANSI 2015). The manufacturers procured their materials from a variety of regional

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sources. In general, the Douglas-fir came from Oregon and Washington. The southern pine came from throughout the pine-producing region. This sampling regime was intended to increase variability in the sample; it was not intended to yield allowable design properties. Each manufacturer selected 30 on-grade southern pine and 30 on-grade Douglas-fir pieces, for a total of 60 crossarms from each species group. All crossarms were untreated, kiln-dried, not yet drilled, and measured approximately 8.9 by 11.4 by 244 cm. Only the Douglas-fir crossarms were incised. In total, 120 pieces were tested.

For the 1995 study, the southern pine samples were sourced from Georgia and the Douglas-fir from Washington. Those crossarms were graded and selected from mill run stock. From these sources, 65 on-grade southern pine and 57 on-grade Douglas-fir samples were selected and analyzed. All specimens were untreated, kiln-dried, and not yet drilled. For each species group, approximately half of the samples were 8.9 by 11.4 by 244 cm, and half were 9.5 by 12.1 by 244 cm. In total, 122 pieces were tested (Barnes and Winandy 2001).

Specifications

For the 2015 study, the following standards and guidelines were followed. Material was graded, stored, and conditioned in accordance with ANSI O5.3-2015 (ANSI 2015). Specimen moisture content was measured with a handheld moisture meter per ASTM D7438-13 (ASTM International 2013). Preliminary specimen measurements, load setups, destructive testing procedures, and data recordings were performed according to ASTM D198-14 (ASTM International 2014). Mechanical properties were adjusted for moisture content differences per ASTM D1990-07 (ASTM International 2007). This method of adjustment is identical to the one found in the *Wood Handbook* (Forest Products Laboratory [FPL] 1999) and referenced by Barnes and Winandy (2001). Fifth-percentile nonparametric lower tolerance limits (NTLs) were calculated as per ASTM D1990-07 and interpolated using NONPAR (FPL 2011). As in Barnes and Winandy (2001), mechanical properties of southern pine and Douglas-fir were assumed to begin to change at or below 21 and 24 percent moisture content (MC), respectively, per the *Wood Handbook* (FPL 1999).

Testing and analysis

Upon receipt, the materials were stored for 2 to 4 weeks in a climate-controlled laboratory at approximately 21°C and 65 percent relative humidity to aid moisture conditioning. A preliminary evaluation was subsequently administered. This evaluation included labeling each specimen with a designated item code and measuring thickness, width, and length in accordance with ASTM D198-14 (ASTM International 2014).

Final weight and MC measurements were delayed until the day of testing. Shortly before destructive testing, weight was measured with a calibrated scale, and MC was measured with a handheld moisture meter in accordance with ASTM D7438-13 (ASTM International 2013).

Destructive bending tests were performed on all specimens to obtain strength (MOR) and stiffness (MOE) values. Consistent with the 1995 study, the 2015 test setup and procedures were performed in accordance with ASTM D198-14 (ASTM International 2014) to ensure cross-study comparability of data.

The destructive tests were performed on an Instron universal testing machine. Fixture setup and third-point loading were executed per the flexure test method procedure within ASTM D198-14 (Fig. 1). A span-to-depth ratio of 17:1 was used.

Each specimen was placed in the machine to simulate the orientation of how a crossarm would be positioned on a utility pole. When applicable, the larger chamfered sides were placed upward in an edgewise (strong-axis) position. This orientation simulates loading from the weight of the wires, not necessarily the wind. Before zeroing the deflectometer, each species was loaded with approximately 1,030 N to ensure proper placement and seating of the load heads. The test was then applied until full rupture. The average length of time until rupture was kept to approximately 5 minutes.

In reviewing the raw data output, one specimen of southern pine was found to have an MOE value more than 7 standard deviations (SD) from the mean. This value appears to have resulted from a data acquisition malfunction in the test machine deflectometer and was determined to be an extreme outlier. The data for the entire specimen were removed owing to the specimen's disproportionate influence on the mean and SD. This reduced the sample size for southern pine from 60 to 59 pieces.

Before analysis, all MOR and MOE values for both the 2015 and 1995 data were adjusted per the *Wood Handbook* (FPL 1999) to make them comparable at a common MC. This moisture adjustment procedure is the same as that recommended in ASTM D1990-07 (ASTM International 2007). The average unadjusted MC of the 2015 crossarms was less than that of the 1995 crossarms. As such, the data from both years were adjusted to an intermediate MC between the two averages; the southern pine values were all adjusted to 16 percent, and the Douglas-fir values were all adjusted to 17 percent. This action permitted close comparison of MOR and MOE at the time of testing while, to the best degree possible, staying within the limitations of the MC adjustment model, which recommends no more than a 5 percent MC adjustment (ASTM International 2007). These adjusted MOR and MOE values were used for all comparisons. In each case, pine was compared with pine and Douglas-fir with Douglas-fir. (Pine was not statistically compared with Douglas-fir.)

The 2015 data were compared with those of the 1995 study within each species group. The cumulative frequency diagrams in Figures 2 through 5 show the MOR and MOE distributions. Independent *t* tests were conducted to

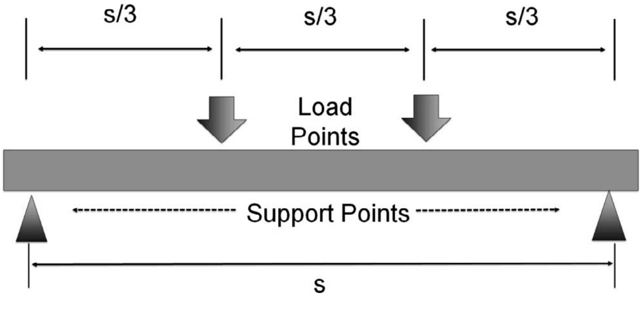

Figure 1.—Third-point loading.

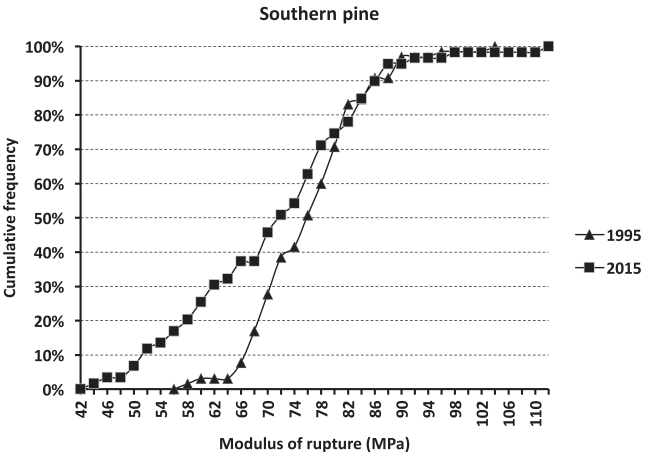

Figure 2.—Cumulative frequency diagram for modulus of rupture of southern pine crossarms adjusted to 16 percent moisture content.

determine if the means of the MOR and MOE of each species group differed between the 1995 and 2015 studies. The results appear in Tables 1 and 2. For the MOR analysis (Table 1), the fifth percentile NTL was also included.

Results

Mean comparisons

Table 1 shows lower mean MOR values for the 2015 data in both species. Southern pine's 7.1 percent difference is statistically significant ($P = 0.009$), while Douglas-fir's 5.1 percent difference is not ($\alpha = 0.05$). Table 2 shows lower mean MOE values for the 2015 data in both species. Douglas-fir's 13.3 percent difference is statistically significant ($P < 0.001$), while southern pine's 2.9 percent difference is not ($\alpha = 0.05$).

Fifth-percentile NTLs

As Table 1 shows, the 2015 data for both species exhibited lower NTL values (75% confidence) for MOR compared with the 1995 values.

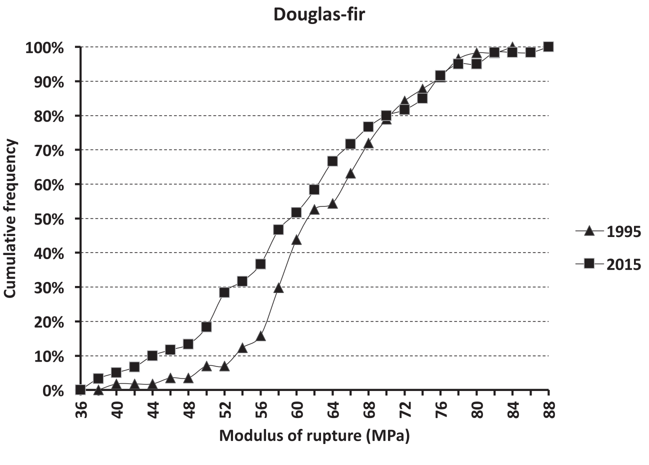

Figure 3.—Cumulative frequency diagram for modulus of rupture of Douglas-fir crossarms adjusted to 17 percent moisture content.

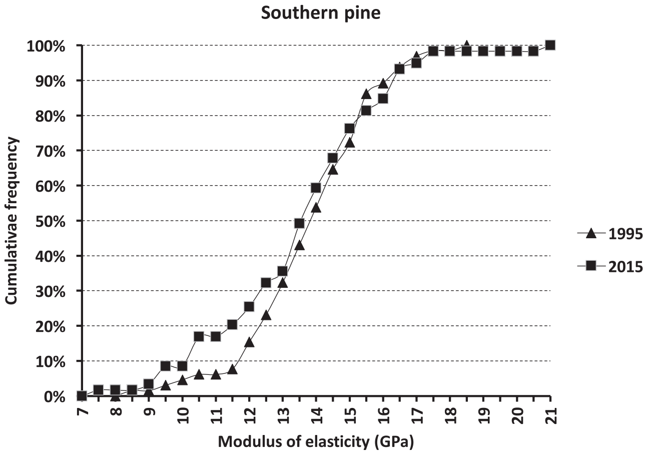

Figure 4.—Cumulative frequency diagram for modulus of elasticity of southern pine crossarms adjusted to 16 percent moisture content.

Distribution comparisons

Moving from right to left in Figure 2, the 1995 and 2015 cumulative distribution curves for the MOR of southern pine begin to diverge starting near the upper quartile. As the slope of the 2015 curve flattens, the distance between the two curves becomes larger. This trend continues until the curves reach their widest divergence below the 10th percentile. The 2015 curve for Douglas-fir in Figure 3 follows a similar pattern, though the divergence is not as wide below the 10th percentile. Both patterns indicate potentially larger differences in MOR in the lower percentiles, as the reduction in the NTL values of Table 1 would suggest. It is important to note, however, that these findings are limited to the samples tested herein.

Moving from right to left in Figure 4, the 1995 and 2015 cumulative distribution curves for the MOE of southern pine are virtually parallel and nearly overlap between the upper and lower quartiles, with only a slight flattening of the slope in the 2015 curve below the lower quartile. In contrast, Figure 5 shows what appears to be a complete negative shift of Douglas-fir's 2015 MOE distribution away from its 1995 counterpart, lending additional support to the significant

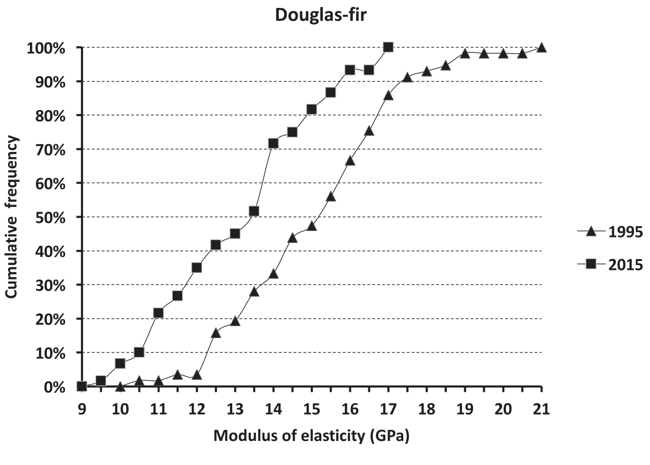

Figure 5.—Cumulative frequency diagram for modulus of elasticity of Douglas-fir crossarms adjusted to 17 percent moisture content.

Table 1.—Results of independent t *tests on the means of adjusted modulus of rupture (MOR) values from 1995 and 2015.*

Species	Year[a]	*n*	Mean MOR (MPa)	SD	Min.	Max.	*t*	df	*P* value[b]	NTL[c]
Pine	1995	65	75.9	8.49	56.4	102.7	2.64	122	0.009**	61.6
	2015	59	70.5	13.76	43.2	111.1				46.0
Douglas-fir	1995	57	63.0	8.89	39.8	82.9	1.70	115	[0.092]	46.4
	2015	60	59.8	11.48	37.7	86.9				38.2

[a] Data for 1995 samples from Barnes and Winandy (2001) were converted from psi to MPa.

[b] Double asterisks indicate the means are significantly different at $\alpha = 0.01$. Brackets indicate no significant difference at $\alpha = 0.05$.

[c] Fifth-percentile nonparametric lower tolerance limits (NTL) were estimated at 75% confidence.

Table 2.—Results of independent t *tests on the means of adjusted modulus of elasticity (MOE) values from 1995 and 2015.*

Species	Year[a]	*n*	Mean MOE (GPa)	SD	Min.	Max.	*t*	df	*P* value[b]
Pine	1995	65	13.8	1.87	8.3	18.0	0.874	122	[0.384]
	2015	59	13.4	2.47	7.2	20.7			
Douglas-fir	1995	57	15.0	2.11	10.3	20.7	5.112	115	<0.001**
	2015	60	13.0	2.02	9.3	16.8			

[a] Data for 1995 samples from Barnes and Winandy (2001) were converted from psi to GPa.

[b] Double asterisks indicate the means are significantly different at $\alpha = 0.01$. Brackets indicated no significant difference at $\alpha = 0.05$.

difference found between the mean MOE values of those two sample years.

Discussion

In both species, the crossarms sampled in 2015 seem to exhibit lower mechanical performance than those sampled in 1995. The statistically significant lower mean MOR value of southern pine is further supported by the cumulative distribution curve divergence below the upper quartile. Likewise, the statistically significant lower mean MOE value of Douglas-fir is further supported by a negative shift of the entire 2015 cumulative frequency distribution. Lower NTL values in the 2015 data of both species seem to indicate a reduction in strength at the fifth percentile for these specimens.

These results should be interpreted within the confines of the sampling. While efforts were made to ensure varied and representative material, the sampling was not intended to be global and typical of all production. Additional testing with a wider regional sampling could offer more insight as to whether crossarms manufactured from these species are changing in strength and stiffness.

Conclusions

This study provided a means of comparing on-grade crossarm and wood quality performance at the resource level over a 20-year interval. Other studies of solid wood products have suggested that strength and stiffness properties have changed over time. This analysis was conducted to investigate and address the concern that mechanical properties might have decreased owing to silvicultural, processing, or other changes. It seemed expedient to compare these data sets from 1995 and 2015 as they were both readily available and well matched.

The results showed a statistically significant ($\alpha = 0.01$) 7.1 percent reduction of mean MOR in southern pine crossarms and a statistically significant ($\alpha = 0.01$) 13.3 percent reduction of mean MOE in Douglas-fir. Distribution analyses also suggested a reduction of strength performance in the lower percentiles of both species. Repeated testing is encouraged to determine what long-term effects this could have on crossarm performance.

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