BENDING PROPERTIES OF WOODEN CROSSARMS

H. M. Barnes, Professor
Forest Products Laboratory
Mississippi State University
Mississippi State, MISSISSIPPI

and

J. E. Winandy, Project Leader
Performance Designed Composites
USDA Forest Service, Forest Products Laboratory
Madison, Wisconsin

ABSTRACT: This report summarizes our comparison of the bending strength of two common sizes of utility crossarms from two species of wood, southern pine (*Pinus* spp.) and Douglas-fir (*Pseudotsuga menziesii*). Data from the testing of mill-run crossarms showed that the southern pine crossarms were usually equivalent to or in a few cases higher in strength than those of Douglas-fir.
Keywords: bending, strength, modulus of rupture, modulus of elasticity, crossarms, southern pine, Douglas-fir

INTRODUCTION

For many years both southern pine and Douglas-fir crossarms have successfully been used to carry line loads on utility poles. However, utility engineers still question the comparative performance of southern pine versus Douglas-fir crossarms. These concerns may be related to the fact that bench mark engineering data for both southern pine and Douglas-fir crossarms originally was derived by testing material from larger diameter trees than are commonly processed today. These questions have recently resurfaced with particular concern about the increased prevalence over the last 10-20-years of crossarms cut from small-diameter timber which results in an increase in juvenile wood. Juvenile wood in softwoods, like southern pine and Douglas-fir, usually has material properties 30-90% of that for mature wood and has far less dimensional stability. It occurs in the first 12-17 years of growth dependent on species. This study compares several mechanical properties of two species of wood crossarms at two commonly used sizes. It presents the utility design engineer with a direct comparison of commercially representative crossarm inventories. It allows a comparison of the crossarms containing juvenile wood, as indicated by boxed pith, to crossarms not exhibiting boxed pith.

METHODS & MATERIALS

Materials and sampling --Crossarms from Douglas-fir (*Pseudotsuga menziesii*) from a Washington mill and southern pine (Pinus spp.) from a Georgia mill were selected for this study. Crossarms for both species measured 8-ft long by 3½- x 4½-inch or 3¾- x 4¾-inch in cross-section. The 3¾- x 4¾-in Douglas-fir and the 3½- x 4½-in southern pine stock were both drawn during a routine run of crossarm production that was surfaced from rough stock at the time of sample selection. In both cases, the independent inspector selecting the stock stood downstream of the mill's grader. The mill's grader was asked to grade for a normal run, which included his marking of reject arms. The selection technique was for the independent inspector to consider every fifth crossarm as a candidate for selection. The reject pieces that had not made grade as evaluated by the mill grader were not considered in the count. If the fifth piece conformed to the specifications listed below, the arm was pulled off the line as a test sample. If the fifth piece did not conform to the below stated specifications, the count began anew to the next fifth piece of the mill's grade of crossarms. No more than five test samples were drawn from each incoming unit of rough-sawn crossarms to allow for a more representative sampling of the available population. The initiation of when to start the count within a lot of incoming arms was random. At the Washington mill, each lot consisted of about 110 arms of incoming rough material. At the Georgia mill, each lot consisted of between 105 and 173 pieces per incoming rough unit. Seven units of incoming rough-sawn crossarms made up of the gross population sampled for each species-size combination.

A slightly different procedure was used with the 3½- x 4½-in Douglas-fir stock and the 3¾- x 4¾-in southern pine stock. Samples from both of these groups were drawn from surfaced, unframed crossarms taken out of inventory at the respective locations. Both gross populations represented a standard mill's production of finished crossarms, from which the reject arms (including re-run and trim pieces) had been purged. Both inventories had been run on a routine basis, without the mill's grader having any knowledge that such production would be sampled for the collection of test pieces. The independent inspector used the same selection technique described above. Again, no more than five test pieces were taken from each unit of crossarms.

Specifications --Prior to the selection process, a comparison was made of the five common crossarm specifications: ANSI 05.3 (ANSI 1995); Edison Electric TD 90 (EEI 1960) for Douglas-fir; Edison Electric TD 91 (EEI 1957) for southern pine; REA Bulletin 1728H-701 (REA 1993); TP Guidelines (Sibert 1991). The sample pieces selected for testing conform to all of those applicable specifications for characteristics related to structural attributes (such as knots, slope of grain, density, decay, insect holes, and breaks). For other non-structural characteristics and features, the most restrictive and/or most comprehensive specification was selected, with the exception of pitch pockets, which were allowed as permitted in the REA Bulletin (1993). In addition, seasoning checks were limited to 1/8-in wide (in addition to the other limitations on length and depth per location). Crossarms with skip dressing in the center section were not accepted, and warped crossarms were not accepted even though the stated specifications allow for such skip and some warp. Sampling conformed to or exceeded the specifications in ASTM D2915-98 (1999). All units of test samples (two at each location with 34 to 35 pieces) were packaged with lath between each row, banded in the presence of the independent inspector, and shipped to the Forest Products Laboratory at Mississippi State University for testing.

Testing and analysis —Crossarms were tested in accordance with ASTM D198-98 (ASTM 1999). Crosshead speed was selected such that failure occurred in six to ten minutes. Mechanical properties begin to change when drying from the green to dry conditions. Generally mechanical properties begin to increase as specimen moisture content drops below the fiber saturation point (fsp). Conversely, mechanical properties decrease as MC increases from dry conditions up to fsp. The Wood Handbook defines a specific critical point, M_p, as the MC at which properties begin to change when using the exponential model of property variation with MC. These points are taken as 21% MC for southern pine and 24% MC for Douglas-fir (FPL 1999). Some of the specimens in each grade-size category had measured moisture content values below the critical point of 21% for southern pine and 24% for Douglas-fir, while others were above. For any specimen having a moisture content below the critical M_p values, the property values (MOE, MOR, and FSPL) were adjusted back to M_p using adjustment procedures defined in the Wood Handbook (FPL 1999). Adjusted property data were then analyzed by covariate analysis and a least squares mean separation technique.

RESULTS AND DISCUSSION

Two differences were noted between the southern pine and Douglas-fir crossarms. The first was the occurrence of boxed pith in southern pine. While none of the Douglas-fir crossarms exhibited boxed pith, 3 1 of thirty-five 3½- x 4½-in and 14 of thirty-five 3¾- x 4¾-in southern pine specimens exhibited boxed pith. The other was that we noted that the edge-relief that resulted in the chamfer on the top edge of southern pine was approximately twice what it was with the Douglas-fir crossarms. This more noticeable chamfer made selecting the top edge in bending tests much easier for the southern pine.

Descriptive statistics for several properties adjusted to the M_p values are given in Table 1

Table 1. Adjusted property values for southern pine and Douglas-fir crossarms.

Species Size	Value	FSPL (psi)	MOR (psi)	MOE (psi)	Density (pcf)
Southern Pine 3½- x 4½-in.	Mean	5,116	9,175	1,806,945	43.4
	Median	5,110	9,168	1,790,210	43.2
	Standard Deviation	849	995	241,234	3.7
	Minimum	3,747	7,267	1,256,427	36.0
	Maximum	6,861	12,297	2,234,652	55.7
Southern Pine 3¾- x 4¾-in	Mean	6,063	9,291	1,869,971	43.6
	Median	6,221	9,420	1,893,465	44.1
	Standard Deviation	1,177	963	258,680	3.06
	Minimum	3,623	6,981	1,105,730	38.0
	Maximum	8,020	11,512	2,204,458	51.6
Douglas-fir 3½- x 4½-in.	Mean	6,298	7,015	1,892,286	35.3
	Median	6,020	6,803	1,823,141	35.1
	Standard Deviation	798	857	294,196	3.5
	Minimum	5,100	5,621	1,319,850	26.7
	Maximum	7,897	8,746	2,436,803	42.4
Douglas-fir 3¾- x 4¾-in	Mean	5,363	7,156	1,951,665	33.5
	Median	5,181	7,135	1,987,515	33.7
	Standard Deviation	629	938	251,997	4.32
	Minimum	4,136	4,752	1,445,736	23.7
	Maximum	6,881	9,100	2,654,570	41.4

for southern pine and Douglas-fir crossarms. The first result to note is the higher than typical density of the tested southern pine compared to the more common density of tested Douglas-fir. As density is directly related to mechanical properties, this inequity needs to be considered when comparing results of these southern pine and Douglas-fir tests. The influence of the grade rules selected on this phenomenon is unknown.

Analysis of MC-adjusted MOE values indicated no significant difference in the MOE of any of the four groups (Figure 1). Subsequent analyses indicated that MOE was a significant covariate in the analysis of the modulus of rupture (MOR).

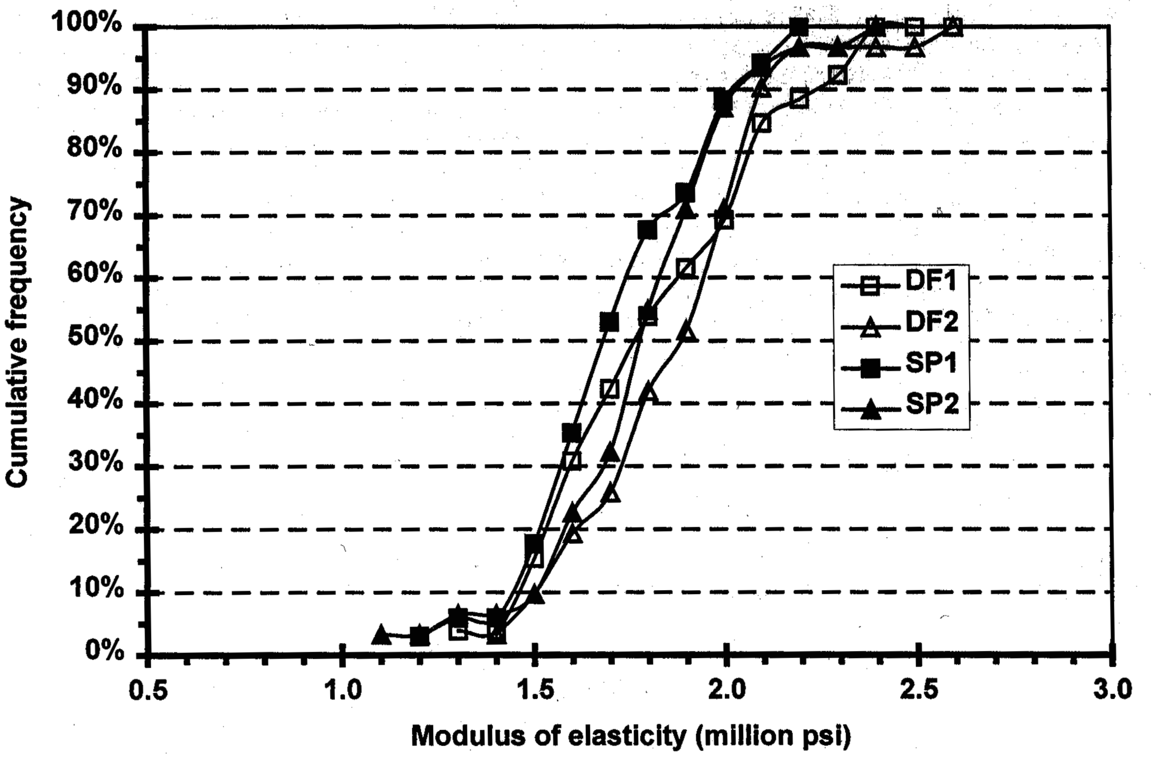

Figure 1. Cumulative frequency diagram for modulus of elasticity of 3½ x 4½-in (1) and 3¾ x 4¾-in (2) southern pine (SP) and Douglas-fir (DF) crossarms.

Two separate analyses were subsequently conducted on the data. In the first, southern pine and Douglas-fir crossarms of equivalent size were directly compared and analyzed. An additional analysis comparing all sizes in a single analysis was also conducted. The least square means from these analyses are shown in Table 2.

Table 2. Least square mean comparisons MOR values adjusted for MOE.

Comparison	Least square mean MOR (psi) value adjusted for MOE
SP1 (3½- x 4½-in) DF1	9,239 a 6,931 b
SP2 (3¾- x 4¾-in) DF2	9,367 a 7,080 b
SP2 SP1 DF2 DF1	9,305 a 9,303 a 7,023 b 6,989 b
Means not followed by a common letter differ one from another at p = 0.05	

The analysis by size groups and the analysis of all data combined showed that the MOR for southern pine was significantly higher than the values for Douglas-fir. This can be seen by comparing the cumulative frequency diagrams shown in Figure 2. We attribute this large difference in MOR, in part, to the large difference in density between the two species (43-45 lb/ft^3 for SP *vs.* 33-36 lb/ft^3 or Douglas-fir). The curves for both sizes of southern pine crossarms indicate they were stronger than the Douglas-fir crossarms. Size was not a factor as strength for crossarms of different sizes was the same within a species (Table 2).

Analysis of the fiber stress data yielded slightly different results. These are shown in Table 3. When analyzed by size, the fiber stress for the smaller Douglas-fir crossarm was significantly higher than that of the smaller southern pine. For the larger crossarm, the reverse was true. When analyzed all together, the trend was DF1 = SP2 > SP1 = DF2 (1 = smaller crossarm; 2 = larger crossarm). This trend can also be seen in the cumulative frequency curves seen in Figure 3. When the two sizes of each species are grouped, there is no significant difference between the two species. This is apparent in Figure 4.

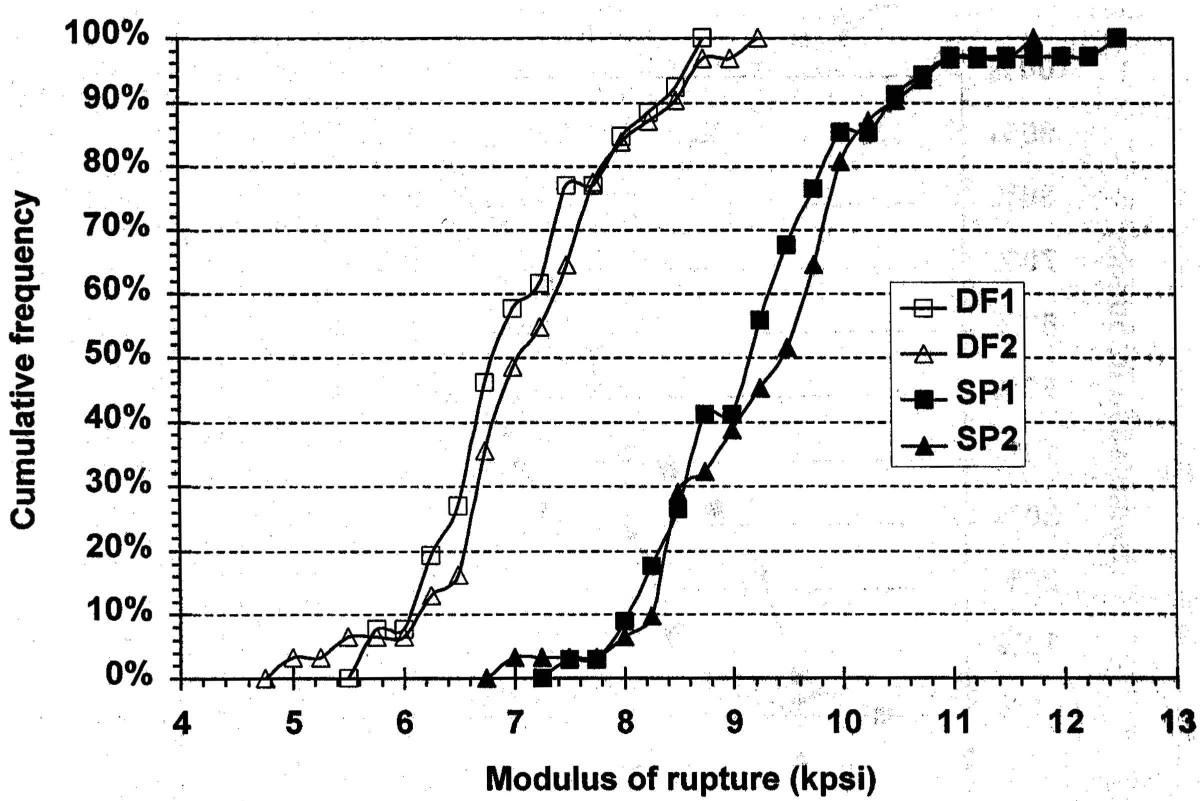

Figure 2. Cumulative frequency diagram for modulus of rupture of 3½ x 4½-in (1) and 3¾ x 4¾-in (2) southern pine (SP) and Douglas-fir (DF) crossarms.

Table 3. Mean comparisons for adjusted least square fiber stress values.

Comparison	Adjusted least square mean fiber stress value (psi)
SP1 (3½- x 4½-in)	5,194 a
DF1	6,196 b
SP2 (3¾- x 4¾-in)	6,141 a
DF2	5,285 b
DF1	6,270 b
SP2	6,079 b
SP1	5,259 a
DF2	5,215 a
Means not followed by a common letter differ one from another at p = 0.05	

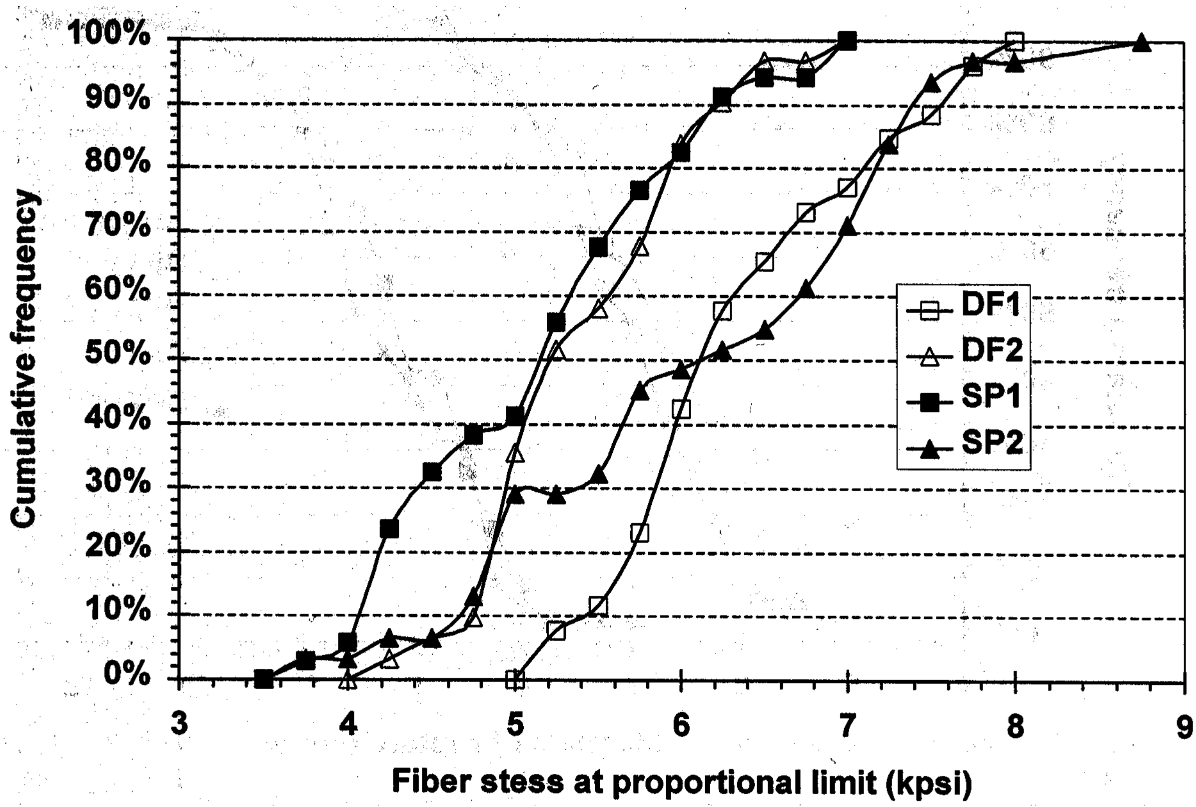

Figure 3. Cumulative frequency diagram for fiber stress of $3^1/_2$x $4^1/_2$-in (1) and $3^3/_4$ x $4^3/_4$-in (2) southern pine (SP) and Douglas-fir (DF) crossarms.

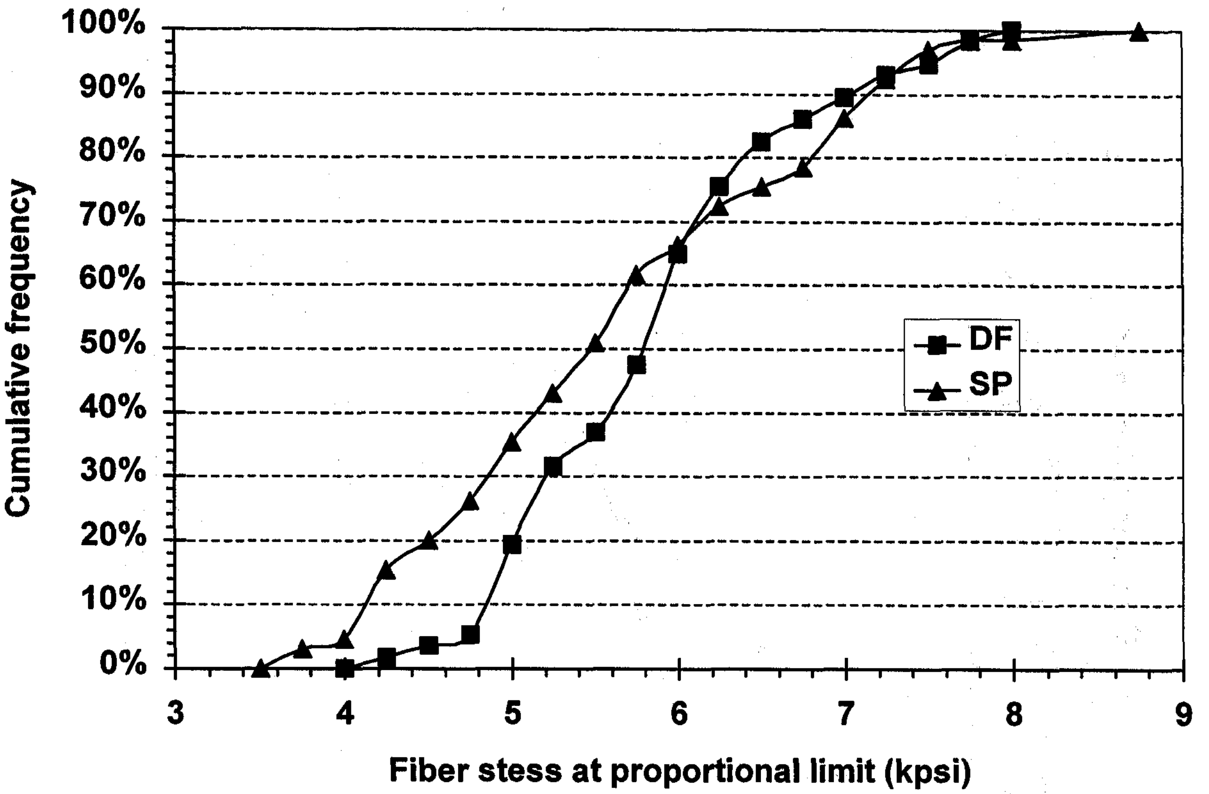

Figure 4. Cumulative frequency diagram for fiber stress of southern pine (SP) and Douglas-fir (DF) crossarms.

SUMMARY AND CONCLUSIONS

The density of the southern pine evaluated in this study was higher than expected for typical lumber production whereas the density of the Douglas-fir was more typical of normal lumber production. The influence of the grade rules selected on this phenomenon is unknown. The modulus of elasticity of southern pine crossarms was shown to be similar to that of Douglas-fir. The MOE of both sizes was equivalent. On the other hand, the bending strength of southern pine crossarms was found to be significantly higher than the strength of Douglas-fir, most likely due to specific gravity differences. Both sizes of crossarms exhibited this same trend with respect to bending strength. With respect to the comparison of fiber stress at the proportional limit between southern pine and Douglas-fir crossarms, a significant interaction related to crossarm size existed. For the smaller crossarm size (3½- x 4½-in), pine exhibited significantly lower FSPL than Douglas-fir. Conversely, when evaluating the larger crossarm size (3¾- x 4¾-in), pine crossarms had significantly higher FSPL than Douglas-fir.

With respect to the potential influence of juvenile wood, as indicated by the presence or absence of boxed-pith, the bending strength of the smaller size southern pine crossarms (of which >80% of specimens exhibited boxed-pith) was shown to be no different than that of the larger sized southern pine of which only 40-45% of the specimens exhibited boxed-pith. In turn, the MOR of both sizes of southern pine with various amounts of boxed pith was generally higher than that of either size of Douglas-fir crossarms which exhibited virtually no juvenile wood, as indicated by the absence of boxed pith.

From a practical standpoint, we believe this study shows that few practical differences exist between the mechanical properties of southern pine and Douglas-fir crossarms and that the presence of juvenile wood (boxed pith) has no deleterious effect on the strength of southern pine crossarms compared to those of Douglas-fir.

LITERATURE CITED

American National Standards Institute. 1995. ANSI 05.3-1995 American National Standard for Wood Products--Solid Sawn-Wood Crossarms and Braces—Specifications and Dimensions. American National Standards Institute, New York, 26 pp.

American Society for Testing and Materials. 1999. ASTM D198-98. Standard test methods of static tests of lumber in structural sizes; ASTM D2915-98 Standard practice for evaluating allowable properties for grades of structural lumber. In: 1999 Book of Standards, Vol. 04.10 Wood, American Society for Testing and Materials, West Conshohocken, PA, 676 pp

Edison Electric Institute. 1957. Specifications for dense southern pine crossarms preservative treated. TD-91, Edison Electric Institute, New York, NY.

Edison Electric Institute. 1960. Specification for Douglas-fir crossarms treated or untreated. TD-90, Edison Electric Institute, New York, NY.

Forest Products Laboratory. 1999. Wood handbook: wood as an engineering material. USDA Forest Service, Forest Products Laboratory, Report FPL-GTR-113, Reprinted by Forest Products Society, Madison, WI.

Rural Electrification Administration. 1993. REA Specification for wood crossarms (solid and laminated), transmission timbers and pole keys, REA Bulletin 1728H-701, September 1993.

Sibert, Lon. 1991. TP interim guidelines for Douglas-fir and southern yellow pine distribution crossarms. Timber Products Inspection, Inc., Conyers, GA.

IN: Proceedings, 97th annual meeting of the American Wood Preservers' Association, Vol. 97, pages 30-38. American Wood Preservers' Association; pp. 30-38 2001