Effect of Juvenile Wood on Shear Parallel and Compression Perpendicular-to-Grain Strength for Loblolly Pine

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ABSTRACT

It is expected that to satisfy the increased demand for forest products, much of the future timber supply will be from improved trees grown on managed plantations. This fast-growth resource will tend to be harvested in short age-rotations and will contain greater proportions of juvenile wood than in current harvests. In anticipation of this resource, definitive information is needed on the influence of juvenile wood on lumber properties so that grading rules or the associated allowable design stresses can be modified as needed. Most information developed to date has concentrated on ultimate tensile stress, modulus of rupture, and modulus of elasticity. This paper reports the results for shear stress parallel to grain and compression perpendicular to grain. The results are of significance to all producers of this product because of the concern that lumber from fast-grown plantations may have lower allowable &sign stresses than currently published for visually graded lumber.

The shear parallel to grain and compression perpendicular strength were measured on more than 340 specimens from a 28-year-old fast-grown plantation of loblolly pine in North Carolina. The average strength of both properties decreased with increasing amounts of juvenile wood in the cross section. Shear strength was insensitive to annual ring orientation and followed the expected shear strength density relationship. Compression perpedicular to grain strength was very sensitive to annual ring orientation. Compression perpendicular to grain strength with loads applied to the radial face, was more sensitive to changes in juvenile wood content than expected.

INTRODUCTION

To satisfy the demand for forest products in the United States, much of the future timber supply will be from genetically improved trees grown on managed plantations. Compared with current timber harvests, this fast-growth resource will tend to be harvested in short-age rotations and will contain greater proportions of juvenile wood. Juvenile wood is the early growth material produced by the tree, usually defined as the material 10-20 rings from the pith, depending on species.

In anticipation of this resource information is needed on what effect increasing juvenile wood content has on lumber properties so that grading rules and the associated allowable design stress can be modified as needed. A significant amount of literature exists on the effect of juvenile wood on clear wood and dimension lumber in softwoods. However, this information has focused primarily on a few mechanical properties, such as modulus of elasticity (MOE), ultimate tensile stress (UTS), and modulus of rupture (MOR). The purpose of this paper is to (1) report bow horizontal shear, and compression perpendicular to gain stress of fast-growth plantation-grown loblolly pine (Pinus taeda) 2 by 4's (38- by 89-mm (2- by 4-in.) lumber) are influenced by varying proportions of juvenile wood and (2) discuss what effect orientation of annual ring has on these results.

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BACKGROUND

In clear wood, the properties that have ken found to influence mechanical behavior include fibril angle, cell length, and specific gravity (a composite of percentage of late wood), cell wall thickness. and lumen diameter (Boone and Chudnoff 1972, Pearson and Gilmore 1971, Bendsten and Senft 1986, Thornquist 1990, Kucera 1994). Juvenile wood has a high fibril angle that causes excessive longitudinal shrinkage, which may be more than 10 times that of mature wood (Yang et al. 1994). Compression wood and spiral grain are also more prevalent in juvenile wood than in mature wood and contribute to excessive longitudinal shrinkage. Further-more, longitudinal shrinkage is greater in early juvenile wood than in late juvenile wood.

In structural lumber, a potential problem of lower mechanical properties of juvenile wood was first observed by Koch (1966) while involved in research to develop straight studs from Southern Pine veneer cores. Even more damaging evidence was found by Moody (1970) and Gerhards (1979). Although these research studies observed differences between juvenile and mature wood neither study was designed to measure the difference. Because of research results like those cited and other research around the world, concern developed in the United States and elsewhere that allowable stresses assigned to lumber do not adquately reflect the changing resource. In the 1980s, researchers began to directly assess the mechanical properties of juvenile material.

In New Zealand, in-grade testing was completed on Radiata pine lumber cut from 40- to 60-year-old (Walford 1982) and 28-year-old stands (Bier and Collins 1984). In Canada, work by Barrett and Kellogg (1989) and Smith et al. (1991) looked at plantation Douglas-fir and red pine. In addition, several studies were conducted in the United States on the bending and tension parallel to grain properties of Douglas Fir and Southern Pine dimension lumber cut from plantations (Pearson 1984, Bendsten et al. 1988, MacPeak et al. 1990, Biblis 1990, Krerschmann and Bendtsen 1992).

Intricate studies of clear wood have produced a clear understanding of the physical property changes that occur as juvenile wood matures and their effect on MOR, compression parallel to grain, and MOE. Several studies on solid-sawn timber provide a good understanding of the effect of juvenile wood on MOR, UTS, and MOE. However, the information available on the effect of juvenile wood on ocher properties critical for design, such as horizontal shear stress. tensile stress perpendicular to grain (T-perp), and compressive stress perpendicular to grain (C-perp) is minimal in comparison. This paper provides information on the effect of various proportions of juvenile wood on shear parallel to grain and C-perp for loblolly pine.

EXPERIMENTAL METHODS

Origin of Sample Material

The sample material was from 700 short (610-mm (2-ft)) sections taken from the undamaged ends of 2.4-m (8-ft) 39- by 89-mm (2- by 4-in.) tension specimens for which the percentage of juvenile content had ken previously determined (Kretschmann and Bendtsen 1992). Juvenile wood for this material and geographic location was defined as anything less than or equal to the eighth growth ring. The lumber for this study came from 100 trees cut from a 28-year-old plantation in Beaufort County, North Carolina owned by the Weyerhaeuser Co. The seed source is unknown, but it is known that the seeds were not from a genetically improved source. The plantation site was an old farm field, not a forested site, and had a site index of 69. The planration was thinned twice (1973 and 1981) and fertilized at least once (1979-1980). This management regime was typical of that anticipated by the Weyerhaeuser Co., at that time, for the production of sawtimber trees in the future. The sample trees averaged 409 mm (16.1 in.) in diameter breast height (dhh), ranging from 280 to 490 mm (11 to 19.3 in.). About half the trees fell in the diameter range of 355 to 420 mm (14 to 16.5 in.).

Specimen Preparation and Testing

The approximately 700 short sections of 2 by 4's were sorted by proportion of juvenile wood and divided equally into two groups. One group was used to cut out shear and compression perpendicular to grain clear wood specimens. The other group was cut into three tension perpendicular to grain, a compact tension fracture and a mode I fracture energy specimens. Only the shear parallel and compression perpendicular to grain results are reported here. The short sections had been stored in conditioned space of 70°F (21°C) and 65% relative humidity. Care was taken to center the specimens in a location on the wide face of the board that provided the most uniform ring orientation across the test segment of the specimen.

Shear

Dimensions of the shear parallel-to-grain specimen used are shown in Figure 1. Testing of the shear block specimens was in accordance with ASTM D 143 except for the specimen width and varied ring orientation.

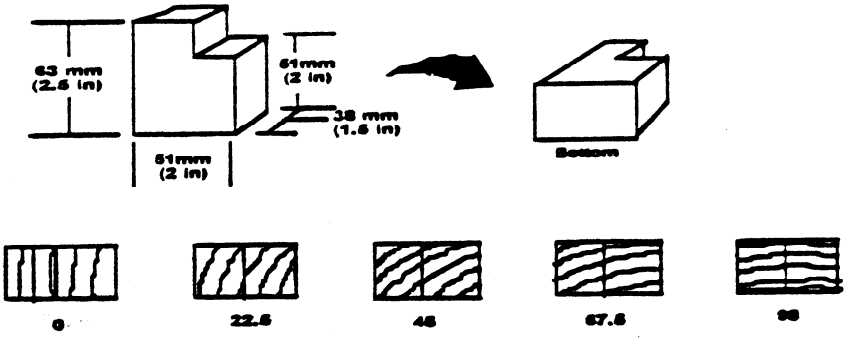

FIGURE 1. Shear parallel-to-grain specimen and orientations tabulated.

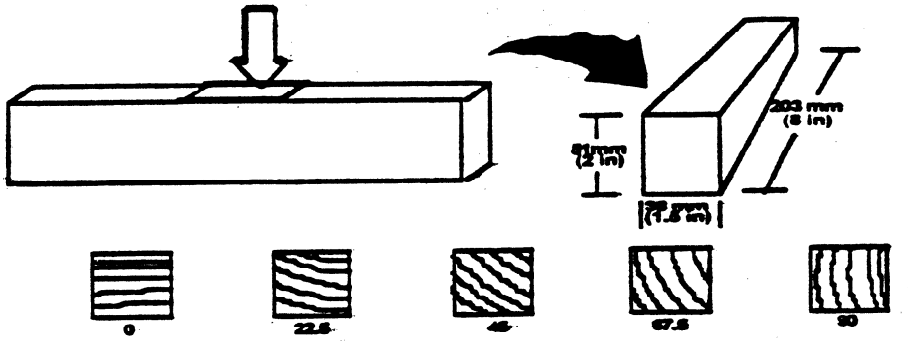

FIGURE 2. Compression perpendicular-to-grain specimen dimensions and annual ring orientations recorded.

Loading rate was 0.6 mm/min (0.024 in/min). The 38-mm-(1.5-in-) thick specimen has been shown to be an acceptable substitution for the standad 51-mm- (2-in-) wide specimen (Bensten and Porter 1978). Each test specimen was classified into one of five relative ring orientations 0°, 22.5°, 45°, 67.5°, and 90° (Figure 1). After testing, density was determined for each specimen using ASTM D2395 procedures (ASTM 1996).

C-perp

The C-perp specimen size was 51 by 38 by 203 mm (2 by 1.5 by 8 in.), which has been shown to give similar results to the 51- by 51-mm (2- by 2-in.) specimen by Kenesh (1968). The load was applied to the 38-mm- (1.5-in-) wide face (Figure 2). Loading rate was 0.3 mm /min (0.012 in/min). Load deflection information was collected electronically until 2.5-mm (0.1-in.) deflection. In addition to load deflection information, each test specimen was classified into one of five relative annual ring orientations 0°, 22.5°, 45°, 67.5°, and 90°. To determine the 1-mm (0.04-in.) deflection compressive stress, a linear regression was fitted to the portion of the curve between 20% and 40% of the maximum load. This curve was then passed through the origin. The load for the 1-mm (0.04-in.) deflection was that taken from this origin. After testing, density was determined for each specimen.

RESULTS

The results for density, shear stress parallel to grain stress, and compression perpendicular to grain stress for the various possible combinations of orientation and percentage juvenile wood content are summarized in Tables 1 to 4.

Sample Sizes

When starting this study, there was a limited number of short sections to choose from in the previous tension study (Kretschmann and Bendtsen 1992). It was hoped that there would be sufficient numbers to get a representative average in all the various juvenile wood content-orientation combinations. As it turned out, there was fairly good distribution of specimens

TABLE I. Density results for horizontal shear parallel-to-gain block shear test specimens. For each cell, the top line is density in kg/m^3, the second line is specific gravity ovendry weight volume at time of test. the third line is moisture content (%), and the bottom line is sample size.

Orientation in degrees	0% Juvenile	1%-20% Juvenile	21%-40% Juvenile	41%-60% Juvenile	61%-80% Juvenile	81%-99% Juvenile	100% Juvenile	Total
0	550 (0.50) 10.2 1	580 (0.52) 10.7 6	540 (0.48) 10.4 11	510 (0.46) 10.8 4	560 (0.50) 9.8 4	490 (0.44) 11.0 6	440 (0.39) 11.3 6	520 (0.46) 10.7 38
22.5	510 (0.45) 10.9 9	560 (0.50) 10.6 10	530 (0.47) 10.7 7	540 (0.48) 10.5 12	490 (0.43) 10.4 8	470 (0.42) 10.6 13	480 (0.43) 10.6 9	510 (0.46) 10.6 68
45	560 (0.50) 10.4 18	520 (0.46) 11.1 21	570 (0.51) 10.3 8	550 (0.49) 10.5 9	530 (0.47) 10.8 11	490 (0.44) 10.5 9	470 (0.42) 10.4 14	530 (0.47) 10.6 90
67.5	550 (0.49) 10.9 17	510 (0.46) 10.8 15	490 (0.43) 10.9 8	510 (0.45) 10.4 5	560 (0.50) 10.4 3	480 (0.42) 10.8 8	480 (0.43) 10.9 7	510 (0.46) 10.8 63
90	530 (0.48) 10.8 43	560 (0.50) 10.7 8	560 (0.50) 10.7 4	520 (0.46) 10.8 11	530 (0.47) 11.0 2	480 (0.43) 11.0 12	460 (0.41) 10.6 4	530 (0.47) 10.8 84
Total	540 (0.48) 10.7 88	530 (0.48) 10.8 60	530 (0.48) 10.5 38	530 (0.47) 10.6 41	520 (0.47) 10.5 28	480 (0.43) 10.8 48	470 (0.42) 10.7 40	520 (0.46) 10.7 343

TABLE 2. Density results for compression perpendicular-to-grain test specimens. For each cell, the top line is density in kg/m^3, the second line is specific gravity ovendry weight volume at time of test, the third line is moisture content (%), and the bottom line is sample size.

Orientation in degrees	0% Juvenile	1%-20% Juvenile	21%-40% Juvenile	41%-60% Juvenile	61%-80% Juvenile	81%-99% Juvenile	100% Juvenile	Total
0	560 (0.50) 11.3 2	550 (0.49) 11.1 5	530 (0.47) 10.9 11	510 (0.45) 10.5 7	490 (0.44) 10.7 6	470 (0.42) 11.1 7	440 (0.39) 11.0 13	490 (0.44) 10.9 51
22.5	530 (0.47) 11.4 6	530 (0.48) 10.7 9	530 (0.48) 10.8 8	540 (0.48) 11.0 8	510 (0.45) 10.5 6	460 (0.41) 11.0 9	480 (0.43) 10.9 3	510 (0.46) 10.9 49
45	540 (0.48) 10.9 21	530 (0.47) 11.5 24	570 (0.51) 11.1 8	530 (0.48) 11.4 9	530 (0.48) 11.1 12	460 (0.41) 11.1 13	450 (0.40) 10.8 13	520 (0.46) 11.2 100
67.5	550 (0.49) 11.3 16	510 (0.45) 11.2 11	510 (0.45) 11.0 4	490 (0.44) 10.8 6	520 (0.47) 10.6 2	490 (0.44) 11.2 9	470 (0.42) 11.6 4	510 (0.46) 11.2 52
90	530 (0.47) 11.2 45	540 (0.48) 11.1 12	500 (0.44) 11.0 8	530 (0.47) 11.2 10	530 (0.47) 11.2 2	470 (0.42) 11.6 10	460 (0.41) 11.2 7	520 (0.46) 11.2 94
Total	540 (0.48) 11.2 90	530 (0.47) 11.2 61	530 (0.47) 11.0 39	520 (0.47) 11.0 40	520 (0.46) 10.8 28	470 (0.42) 11.2 48	450 (0.40) 11.0 40	510 (0.46) 11.1 346

TABLE 3. Results for horizontal shear parallel-to-grain block shear test specimens. For each cell, the top line is horizontal shear stress in MPa, the middle line is horizontal shear stress in lb/in^2, and the bottom line is sample size.

Orientation in degrees	0% Juvenile	1%-20% Juvenile	21%-40% Juvenile	41%-60% Juvenile	61%-80% Juvenile	81%-99% Juvenile	100% Juvenile	Total
0	9.47 (1370) 1	9.36 (1360) 6	8.32 (1210) 11	8.22 (1190) 4	8.76 (1270) 4	7.24 (1050) 6	6.95 (1010) 6	8.16 (1180) 38
22.5	8.60 (1250) 9	8.96 (1300) 10	8.88 (1290) 7	8.36 (1210) 12	7.62 (1100) 8	7.29 (1060) 13	8.22 (1190) 9	8.23 (1190) 68
45	8.84 (1280) 18	8.29 (1200) 21	9.47 (1370) 8	8.87 (1290) 9	8.75 (1270) 11	7.45 (1080) 9	6.97 (1010) 14	8.33 (1210) 90
67.5	8.57 (1240) 17	8.18 (1190) 15	7.44 (1080) 8	8.36 (1210) 5	9.71 (1410) 3	7.38 (1070) 8	7.34 (1060) 7	8.08 (1170) 63
90	8.25 (1200) 43	8.78 (1270) 8	8.32 (1210) 4	7.91 (1150) 11	8.15 (1180) 2	7.27 (1050) 12	7.01 (1020) 4	8.06 (1170) 84
Total	8.49 (1230) 88	8.54 (1240) 60	8.48 (1230) 38	8.34 (1210) 41	8.49 (1230) 28	7.32 (1060) 48	7.32 (1060) 40	8.18 (1190) 343

TABLE 4. Results for compression perpendicular test specimens. For each cell, the top line is compression perpendicular-to-grain stress at 1-mm (0.44-in) deflection in MPa, the middie line is compression perpendicular-to-grain stress in lb/in^2, and the bottom line is sample size.

Orientation in degrees	0% Juvenile	1%-20% Juvenile	21%-40% Juvenile	41%-60% Juvenile	61%-80% Juvenile	81%-99% Juvenile	100% Juvenile	Total
0	7.04 (1020) 2	6.85 (990) 5	6.70 (970) 11	6.78 (980) 7	7.23 (1050) 6	6.72 (970) 7	7.54 (1090) 13	7.01 (1020) 51
22.5	6.81 (990) 6	6.55 (950) 9	6.54 (950) 8	7.14 (1030) 8	7.09 (1030) 6	6.07 (880) 9	7.99 (1160) 3	6.74 (980) 49
45	7.98 (1160) 21	6.99 (1010) 24	7.34 (1060) 8	7.57 (1100) 9	7.65 (1110) 12	6.84 (990) 13	6.76 (980) 13	7.31 (1060) 100
67.5	11.09 (1610) 16	9.52 (1380) 11	10.52 (1530) 4	9.81 (1420) 6	11.20 (1620) 2	8.89 (1290) 9	8.34 (1210) 4	9.98 (1450) 52
90	11.09 (1610) 45	11.21 (1630) 12	10.42 (1510) 8	10.65 (1540) 10	10.28 (1490) 2	8.58 (1240) 10	8.32 (1210) 7	10.51 (1520) 94
Total	9.99 (1450) 90	8.20 (1190) 61	7.96 (1150) 39	8.45 (1220) 40	7.88 (1140) 28	7.43 (1080) 48	7.54 (1090) 40	8.45 (1230) 346

throughout the possible ceils. Twenty eight of the thirty five test cells had more than five specimens (Tables 1-2). It is believed that there is sufficient numbers in the cells to examine average trends. Even though the C-perp and shear specimens were taken from the same location in the piece, there are differences in sample sizes between shear and C-perp in the various cells. The differences are a result of variation between ring position at point of contact in the thicker C-perp specimen and ring orientation across the shear plane.

Density

The overall density of the test specimens 520 kg/m^3 (0.46 specific gravity (SC)) was 10% less than the species average of 570 kg/m^3 (0.51 SG) (FPL 1987). As expected the density decreased as the percentage of juvenile wood increased. The largest decrease in density occurred for specimens with 80% or more juvenile wood content (Figure 3). The 100% juvenile wood material was approximately 15% less than the 0% juvenile wood material.

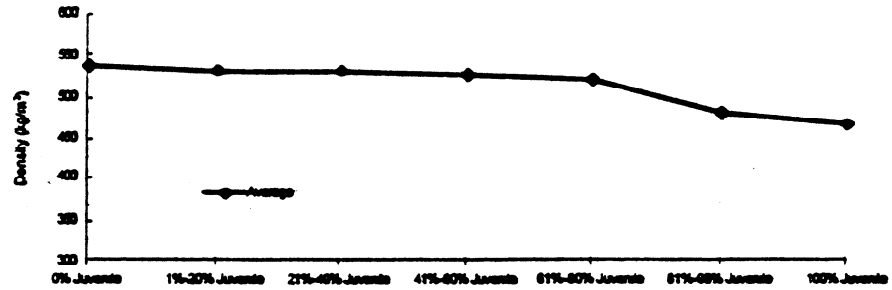

FIGURE 3. The effect of juvenile wood on density (C-perp data).

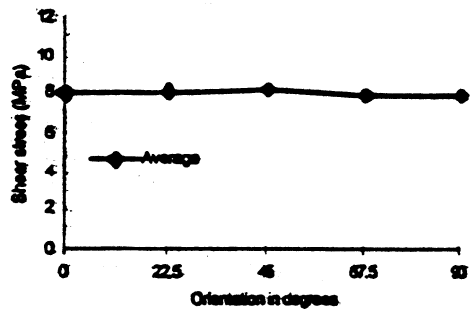

FIGURE 4. The effect of annual ring orientation on shear strength parallel to train.

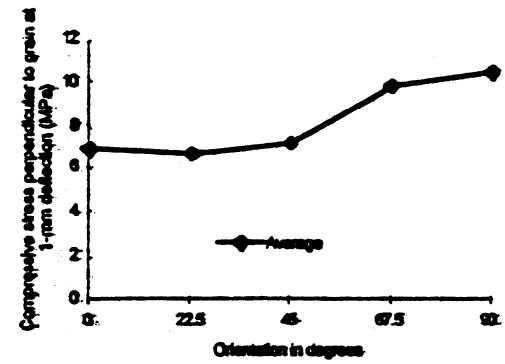

FIGURE 5. The effect on annual ring orientation on compressive stress perpendicular to grain.

Moisture Content

The average moister content for all specimens are listed in Tables 1-2. All cells were conditioned to similar moisture content values of approximately 11%. The shear specimens tend to be slightly dryer then the C-perp specimens.

Orientation

For this material, annual ring orientation bad little effect on shear parallel strength. The overall average varied little for each orientation (Figure 4). As might be expected, given the distinctive earlywood–latewood bands of southern pine, C-perp was sensitive to orientation. The 67.5 to 90 degree orientation was 30% to 35% stronger than the other the orienrations (Figure 5).

Horizontal Shear Strength

The test result for horizontal shear are summarized in Table 3. The shear results appear to be governed primar ily by the density. All orientations appear to follow the same general trend (Figure 6). As would be suggested by the lower average density, the overall test average of the sample, 8.18 MPa (1.190 lb/in^2), was less than the species average in ASTM D2555, 9.58 MPa (1,390 lb/in^2.). The change in shear strength of 1.2 MPa (189 lb/in^2) between mature and juvenile material is what would be predicted from the change in density using a published shear-density relationship for softwoods (FPL 1987). There is again a noticeable shift in average properties for material containing more than 80% juvenile wood (Figure 7), which mirrors the behavior of density.

Compression Perpendicular-to-Grain Strength

The test results for C-perp are summarized in Table 4. ASTM D143 suggests loading the specimens on the tangential face (90 degree orientation. Figure 2). The overall average of the 90 degree orientation is 10.5 MPa (1.524 lb/in^2), which is more than, the species average prediction using the dry/green ratio from ASTM D2555 of 9.3 MPa (1,350 lb/in^2). The 67.5 and 90 degee orientation averages behave similarly and are much more sensitive to juvenile wood content than the other orientations (Figure 8). The 67.5 and 90 degree orientation averages also show more of a decrease in properties (25%) than would be suggested by their change in density. The estimated change in properties

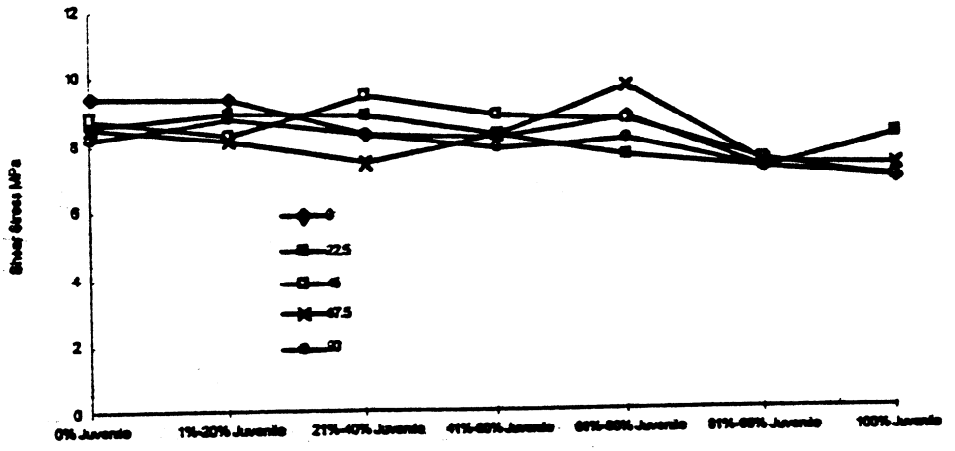

FIGURE 6. - The effect of juvenile wood on shear strength parallel to grain for various annual ring orientations.

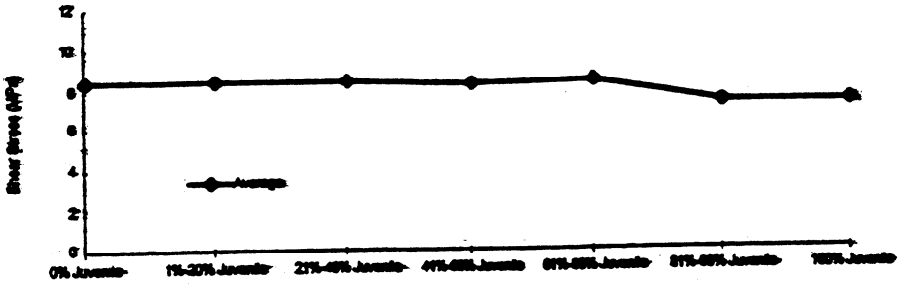

FIGURE 7. - The effect of juvenile wood on average shear strength.

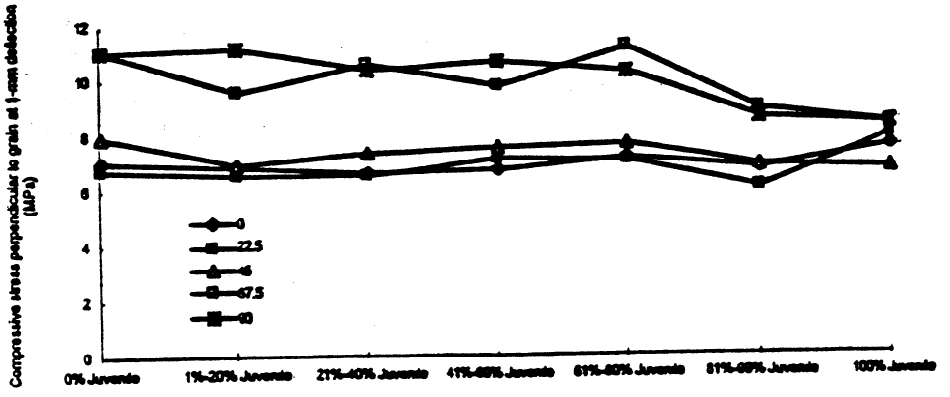

FIGURE 8. -The effect of juvenile wood on compressive strength perpendicular to grain at 1-mm (0.044 deflection for various annual ring orientations.

that would be predicted from the change in density is 1.3 MPa (190 lb/in^2), and the observed shift is nearly eight times that at 10.1 MPa (400 lb/in^2).

CONCLUSIONS

The results of this study indicate the following for this sample of loblolly pine:

- Shear strength was insensitive to annual ring orientation.
- Changes in shear strength resulting from increases in juvenile wood content can be adequately predicted by monitoring density.
- Orientation at which the load is applied has a significant impact on the C-perp strength
- C-perp strength for loads applied to the radial face a more sensitive to changes in juvenile content than are C-perp strength for loads applied to the tangential face up to 45 degree face.
- C-perp strength for loads applied to the radial face are more affected by juvenile wood content than would be suggested by density alone.

REFERENCES

ASTM. 1996. American Society for Testing and Materials. Philadelphia. PA

D–143–94. Standard Methods for Testing Small Clear Specimens of Timbers.

D–2395–93. Standard Test Methods for Specific Gravity of Wood and Wood-Based Materials.

D–2555–88. Standard Test Methods for Establishing Clear Wood Strength Values.

Barrett, J.D.; Kellogg, R.M. 1989. Chapter 5: Strength and stiffness of dimension lumber. Second Growth Douglas-fir: Its Management and Conversion for Value. FORINTEK Canada Corp. April 1989 SP–32 ISSN 0824–2119. p. 50–58.

Bendtsen, B.A.; Porter, Sheilda. 1978. Comparison of results from standard 2-in. with 1-1/2-inch shear block tests. Forest Products Journal 28(7).

Bendtsen, B.A.; Senft, John. 1986. Mechanical and anatomical properties in individual growth rings of Plantation-grown eastern cottonwood and loblolly pine. Wood and Fiber Science, 18(1): 23–38.

Bendtsen, B. Alan; Plantinga, Pamela L.; Sneilgrove, Thomas A. 1988. The influence of juvenile wood on the mechanical properties of 2 by 4's cut from Douglas-fir plantations. In: Proceedings of the 1988 International Conference on Timber Engineering Volume 1.

Biblis E.J. 1990. Properties and grade yield of lumber from a 27-year-old slash pine plantation. Forest Products Journal 40(3): 21–24.

Bier, H. ; Collins, M.J. 1984. Bending properties of 100 by 50 mm structural timber from a 28-year-old stand of New Zealand radiata pine. New Zealand FS Reprint 1774. Presented to IUFRO Group S5.02. Xalapa, Mexico. Dec. 1984.

Boone, R.S.; Chudnoff, M. 1972. Compression wood formation and other characteristics of plantation-grown Pinus caribaea. Res. Pap. ITF–13. Puerto Rico: U.S. Department of Agriculture, Forest Service.

FPL. 1987. Wood handbook: Wood as an engineering material. Agric. Handb. 72. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Gerhards, C.C. 1979. Effect of high-temperature drying on tensile strength of Douglas-fir 2 by 4's. Forest Products Journal 29(3): 39–46.

Kenesh, R.H. 1968. Strength and elastic properties of wood in transverse compression. Forest Products Journal 18(1): 65–72.

Kretschmann, David E.; Bendtsen, B. Alan. 1992. Ultimate tensile stress and modulus of elasticity of fast-grown plantation loblolly pine lumber. Wood and Fiber Science 24(2): 189– 203.

Koch, P. 1966. Straight studs from Southern Pine veneer cores. Res. Pap. SO–25. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, 35 p.

Kucera, Bohumil. 1994. A hypothesis relating current annual height increment to juvenile wood formation in Norway spruce. Wood and Fiber Science 26(1): 152–167.

MacPeak, Malcolm D.; Burhart, L. F.; Weldon, D. 1990. Comparison of grade, yield, and mechanical properties of lumber produced from young fast-grown and older slow-grown planted slash pine. Forest Prod. Journal 40(1): 11–14.

Moody, R.C. 1970. Tensile strength of fingerjoints in pith-associated and nonpith-associated Southern Pine lumber. Res. Pap. FPL 138. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Product Laboratory.

Pearson. R.G. 1984. Characteristics of structural importance of clear wood and lumber from fast-grown loblolly pine stands. In: Symposium on Utilization of the Changing Wood Resource in the Southern United States. North Carolina State University, June 12–13, 1984.

Smith, I.S. Alkan; Chui, Y.H. 1991, Variation of dynamic properties and static bending strength of a plantation grown red pine. Journal of Inst. Wood Sci. 12 (4): 221–224.

Thornquist, Thomas. 1990. Juvenile wood in coniferous trees. The Swedish University of Agricultural Sciences. Department of Forest-Industry-Market Studies. Report 10.

Walford, G.B. 1982 Current knowledge of the in-grade bending strength of New Zealand radiata pine. FRI Bull. 15. New Zealand.

Ying L.; Kretschmann, D.E.; Bendtsen, B.A. 1994. Longitudinal shrinkage in fast-grown loblolly pine plantation wood. Forest Products J. 44(1):58–62.

S.Y. Zhang, R. Gosselin and C. Chauret, 1997.
Timber Management Toward Wood Quality and
End-Product Value. Proceedings of the CTIA/IUFRO
International Wood Quality Workshop,
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