Effect of Earlywood and Latewood on Stress-Wave Measurements Parallel to the Grain

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ABSTRACT. Stress-wave propagation is being explored as a nondestructive test for wood. The influence of earlywood and latewood on transmission speed of stress waves is one subject requiring further investigation. In this study, stress-wave times and amplitudes parallel to the grain were sensed by an accelerometer placed in contact with earlywood or latewood in flatsawed 2 by 4's of Sitka spruce and southern pine. Timing and amplitude were not consistently affected by sensing on earlywood or latewood.

ELECTROMECHANICAL MACHINES have been used in lumber mills for many years to stress grade lumber nondestructively, based on a short-span evaluation. A machine using stress waves could nondestructively stress grade lumber on both a short and a long span basis, and — because stress waves travel very fast — such a machine would be potentially faster than the electromechanical graders. Two long span stress-wave machines are currently in use to measure the stiffness (modulus of elasticity) of laminating stock. Similar procedures are used in particleboard testing.[1]

Research on the practicality of stress waves for grading is proceeding through development of equipment and also through further study of wave propagation in wood. Such study includes the influence of specific lumber characteristics on the speed of stress waves along the grain. The influence of earlywood and latewood on wave transmission is one subject under investigation.

This study was undertaken to evaluate whether stress-wave speed and amplitude are significantly different when sensed in earlywood than in latewood. Previous studies seemingly disagree on whether there is a difference. Burmester[2] presented one set of data indicating that stress-wave speed was about the same for isolated latewood as for whole wood, but that it was slower in isolated earlywood. Another set of Burmester's data, however, indicated that speed was about the same in adjacent layers of earlywood and latewood. Yiannos and Taylor[3] reported that stress-wave speed was higher in latewood portions than in adjacent earlywood portions of thin wood strips.

If stress-wave timing parallel to grain is dramatically growth-ring dependent in lumber, then suitable adjustments would be required in applying stress waves to lumber grading.

Experimental Procedure

Sitka spruce and southern pine were chosen for this study because the annual rings of Sitka spruce have a gradual transition from earlywood to latewood, while those for southern pine have an abrupt transition.

Five nominal 2 by 4's, 6 feet long, of clear, straight-grained wood were sought for each species. The pieces obtained were essentially flatsawed with no recognizable slope to the grain except that one of the southern pine specimens had spiral grain of 1 in 14.5 and another had rings oriented halfway between flatsawed and quartersawed.

The specimens were conditioned at 73°F and 50 percent relative humidity. Pertinent physical properties of the specimens are shown in Table 1.

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[1] Pellerin, R. F., and C. R. Morschauser. 1973. Nondestructive testing of particleboard. Proc. Seventh Particleboard Symp. Washington State Univ., Pullman, Wash. pp. 251-260.

[2] Burmester, A. 1965. Relationshi between sound velocity and the morphological, physical and mechanical properties of wood. Holz als Roh- und Werkstoff 23(6):227-236.

[3] Yiannos, P. N., and D. L. Taylor. 1967. Dynamic modulus of thin wood sections. Tappi 50(1):40-47.

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TABLE 1. - *Selected physical properties of 2 by 4 test specimens.*

Species	Specimen No.	Rings per inch	MC[1] (%)	Density (pcf)	Remarks
Sitka spruce	1	6	9.5	26.2	Flatsawed, straight grained
	2	9	9.7	25.0	Flatsawed, straight grained
	3	8	9.5	24.4	Flatsawed, straight grained
	4	12	9.5	24.9	Flatsawed, straight grained
	5	13	9.7	25.8	Flatsawed, straight grained
Southern pine	4050	8	9.6	31.4	Flatsawed, straight grained
	4107	7	9.5	35.0	Flatsawed, straight grained
	6095	4	8.8	41.8	Flatsawed, straight grained
	5047	6	9.4	37.5	Bias sawed, straight grained
	4021	3-1/2	8.5	32.6	Flatsawed, spiral grained

[1] Ovendry basis

An impact stress-wave instrument developed at Washington State University was used in the study.[4] The device includes a solenoid impactor, two accelerometers for sensing the stress wave, a microsecond timer, and circuitry to convert the accelerometer signals to pulses. The pulses are used to start and stop the timer. The accelerometers used in this study (Fig. 1) are of the same size normally used in lumber and particleboard applications. These accelerometers have a base sufficiently large to overlay adjacent earlywood and

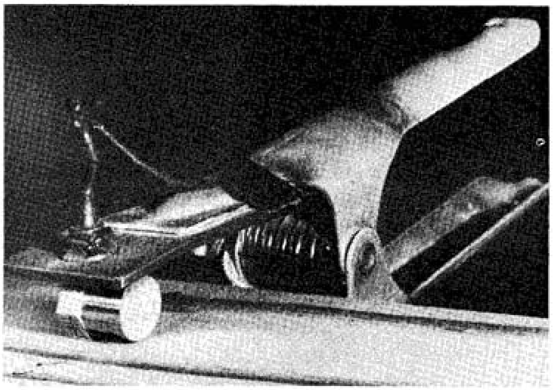

Figure 1. - Accelerometer (Columbia Model No. 302-6), used with the impact stress wave instrument, is clamped onto earlywood of a specimen.

TABLE 2. - *Stress wave transit times in Sitka spruce 2 by 4's.*

Pulse transit distance (in.)	Specimen No. 1		2		3		4		5	
	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)
6	25	26	21	22	21	22	22	23	22	21
12	54	54	45	44	48	49	48	45	45	45
18	81	82	69	70	71	71	71	73	70	71
24	109	108	94	94	96	97	96	97	95	95
30	136	137	119	120	120	121	122	121	121	121
36	161	164	144	145	148	147	148	149	146	144
42	190	190	171	172	172	172	177	178	172	173
48	218	220	197	198	201	199	202	203	202	199
54	245	247	224	223	230	227	229	230	226	223
60	274	276	250	250	253	250	257	258	254	250
66	301	303	274	274	280	277	284	286	277	278

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[4] Gerhards, Charles C. 1978. Comparison of Two Nondestructive Instruments for Measuring Pulse Transit Time in Wood. Wood Sci. 11(1):13-16.

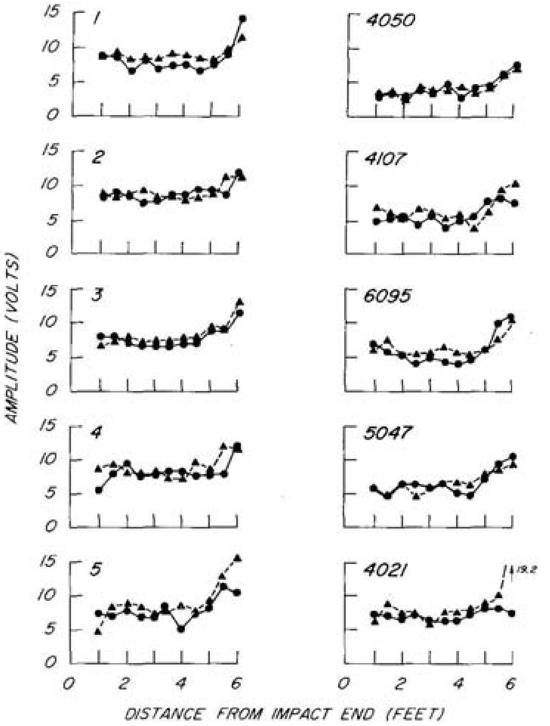

Figure 2. - Maximum amplitude of first pulse from the second accelerometer. Dashed line is earlywood, solid line is latewood.

latewood bands as would often occur in practice.

Each 6-foot-long piece was marked at 6-inch intervals lengthwise on one of the wide, flatsawed faces; the last mark was about 1/10 inch from the end opposite the designated impact end. One accelerometer was fixed at the middle of the wide face at the first 6-inch mark on a specimen. The second accelerometer was clamped at each succeeding 6-inch interval mark on the same wide face on bands of either earlywood or latewood. The specimen was impacted at the end nearest the fixed-position accelerometer, and the resultant stress wave was timed between the two accelerometers. Earlywood and latewood bands tested were adjacent to each other. The accelerometer base was small enough to clamp onto the earlywood of most specimens, particularly with Sitka spruce. Few of the latewood bands, however, were as wide as the accelerometer base, thus some overlap to earlywood occurred.

In addition, the electrical output of the second accelerometer response to the stress wave was monitored with a storage oscilloscope. The maximum voltage amplitude of the first pulse appearing on the oscilloscope was recorded (Fig. 2).

Results and Discussion

The stress-wave times measured to earlywood and latewood positions are shown for the Sitka spruce in Table 2 and for the southern pine in Table 3. Those data suggest that stress-wave timing does not consistently favor either earlywood or latewood. In fact, the differences between the transit times for adjacent earlywood and latewood were generally small, averaging less than 1 microsecond (µs). The maximum difference for any one interval

TABLE 3. - *Stress wave transit times in southern pine 2 by 4's*

	Specimen No.									
	4050		4107		6095		5047		4021	
Pulse transit distance (in.)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)	Early-wood (µs)	Late-wood (µs)
6	25	26	27	29	50	49	29	29	25	25
12	55	54	55	54	94	96	56	59	53	49
18	83	79	83	83	143	143	83	85	80	79
24	106	105	108	110	184	186	112	115	109	110
30	136	135	137	139	227	220	140	140	141	135
36	162	162	166	167	260	261	166	167	165	166
42	189	193	194	194	305	307	195	196	199	196
48	218	218	220	222	344	345	224	232	224	227
54	246	249	244	246	382	381	254	255	258	255
60	275	273	281	280	420	418	284	283	285	287
66	298	299	302	302	454	450	308	309	313	312

mark did not exceed 4 μs for spruce and 8 μs for pine. The standard deviations of the differences between adjacent earlywood and latewood values are 1.6 μs for the spruce and 2.5 μs for the pine.

The amplitude measurements of the first pulse from the second accelerometer are shown in Figure 2 for both species. The voltage amplitudes are sensitive to the equipment and specimen and thus are only useful here in a relative sense. Overall, the amplitudes are higher for Sitka spruce than for southern pine. This may largely be a result of the lower density of Sitka spruce, although the lowest amplitudes occurred in specimen 4050 which happened to have the lowest density of the southern pine specimens. The amplitudes also tended to be slightly higher, but not consistently so, when measured over earlywood than over latewood. The average difference in amplitude favored earlywood by about 0.5 volt. The standard deviations of the differences in amplitude between adjacent earlywood and latewood values were 1.4 volts for spruce and 1.9 volts for pine.

One other interesting feature of the measurements is that the amplitude generally increased over the last one-half foot or so of the specimen length. This probably resulted from the action of the reflecting tensile wave on the accelerometer. The reflective tensile wave would cause the same direction of accelerometer movement as the induced compression wave.[5]

Conclusion

The timing and amplitude sensing of stress-waves in lumber does not seem to be appreciably affected by whether the accelerometer is centered over earlywood or over latewood.

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[5] Bertholf, L. D. 1965. Use of elementary stress wave theory for prediction of dynamic strain in wood. Div. Indust. Res. Inst. Tech., Washington State Univ. Bull. 291. Pullman, Wash.