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Using Modulus of Elasticity as the Sorting Criterion in the Manufacture of Lodgepole Pine Laminated Decking

A Pilot Study

Robert J. Ross
Robert J. Hoyle

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Abstract

The research presented in this research note was conducted to examine the potential to use lodgepole pine boards in laminated roof decking. A sample of visually graded lodgepole pine boards was obtained and evaluated. Modulus of elasticity (MOE), moisture content, specific gravity, and visual grade of each specimen were determined. Three-ply laminates were then prepared from the sample boards. Four types of laminates were prepared, based on either the visual grade or MOE of the boards used. Because bending MOE and strength are important mechanical properties for wood products in roof deck applications, each laminate was then tested in flatwise bending, and its MOE and strength were calculated. Results showed that the MOE and strength of laminates were dependent on visual grade of the boards. More importantly, using MOE as the sorting criterion and strategically placing boards in a laminate based on MOE of the boards produced laminates with greater modulus and strength. These results indicate that lodgepole pine can be used in decking applications.

Keywords: Laminate, laminated decking, lodgepole pine boards, modulus of elasticity, strength

Preface

The study summarized in this research note was conducted by Professor Robert J. Hoyle (deceased), P.E., when he was a faculty member at Washington State University. Professor Hoyle conducted the study to assist an industrial cooperator in determining the potential of using lodgepole pine boards for laminated roof decking. The information presented in his report is still pertinent today, as researchers and land managers continue to look for ways to use woody materials. The final report from that study serves as the basis for this research note.

Conversion table

English unit	Conversion factor	SI unit
foot (ft)	3.048×10^{-1}	meter (m)
inch (in.)	2.54×10^{1}	millimeter (mm)
pound per square inch (lbf in^{-2})	6.894757	kilopascal (kPa)

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A Pilot Study

Robert J. Ross, Supervisory Research General Engineer
USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA

Robert J. Hoyle, Professor of Civil Engineering (deceased)
Washington State University, Pullman, Washington, USA

Introduction

Developing uses for woody materials is important to forest land managers throughout the world. Discovering economically viable products that would help use material from over-stocked, fire-prone lands is especially critical to allow land managers to enact forest management practices that will ultimately improve forest health, decrease fire risk, and provide an economic boost to rural economies.

Research on use of wood in engineering materials and products has been on-going at universities and government laboratories for many years. Many of the earliest efforts were targeted at demonstrating that by coupling fundamental engineering principles with a knowledge of wood science, engineered products that are economically and technically viable can be developed. An example is early research efforts to develop glued-laminated timber (Wilson 1939) and subsequent efforts to investigate using a range of wood species in making laminated timbers (Hernandez and Moody 1992; Hernandez and others 2005; Janowiak and others 1995; Manbeck and others 1993; Marx and Moody 1981a, 1981b; Moody 1974; Moody and others 1993; Shedlauskus and others 1996).

Recently, there has been a renewed interest in research on laminated wood products. Specifically, the wood products research community has been investigating laminating boards or lumber pieces together to make panels for use in wall, flooring, and roofing applications (Williamson and Ross 2016).

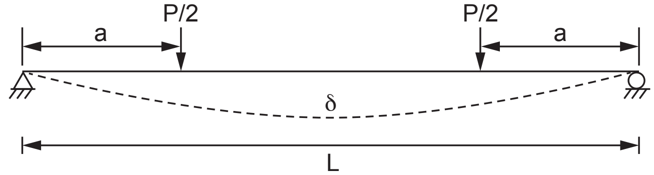
The study summarized in this research note was conducted to examine the potential of using appearance grade lodgepole pine boards in a face-laminated, parallel-oriented product for roof decking (Hoyle 1970). Its specific objective was to investigate the modulus of elasticity (MOE) and bending strength of a sample of lodgepole pine boards and the laminated material made from them.

Materials and Methods

A random sample of lodgepole pine boards was obtained from an industrial cooperator. The sample consisted of 166 nominal 1- by 6-in. 8-ft-long boards with the following nonstructural appearance grades: D-Select & No. 1 Common, No. 2 Common, No. 3 Common, and No. 4 Common. All boards were visually graded by the cooperator in accordance with the grading criteria used at the time. Upon receipt at Washington State University's Wood Products Laboratory, each specimen's dimensions, weight, and moisture content were determined. Static bending MOE was determined using a third-point loading test setup (Fig. 1). All MOE values were adjusted to a 12% moisture content level per ASTM D2555 (ASTM 2017).

The individual board specimens were then used to make nominal 3- by 6-in. three-ply, face-laminated, parallel-oriented planks. Four types of laminated planks were prepared, based on visual grades and MOE values of the lumber specimens, as shown in Table 1.

The laminated specimens were then tested to failure in a flatwise bending mode, using the test setup illustrated in Figure 1. A span (L) of 72 in. was used, with loading at 24-in. intervals (a). Actual specimen dimensions were 2.25 in. thick, 5.5 in. wide, and 96 in. long. These dimensions provided for an approximate span-to-depth ratio of 32. From the load and deflection data collected, MOE



$$\text{MOE} = \frac{Pa(3L^2 - 4a^2)}{48I\delta}$$

Figure 1. Bending test setup used to measure the modulus of elasticity (MOE) and strength of the specimens in this study.

Table 1. Lamination selection criteria for the four groups

Laminate group	Face grade	Core grade	Back grade
A	No. 3 Common	No. 4 Common	No. 4 Common
B	No. 2 Common	No. 3 Common	No. 4 Common
C	D-Select or No. 1 Common	No. 3 Common	No. 4 Common
D	Upper and middle MOE value boards	Lowest MOE boards	Upper and middle MOE value boards

Table 2. Average modulus of elasticity (MOE) values for the boards used in this study

Visual grade	MOE ($\times 10^6$ lb/in^2)	Number of specimens
D Select and No. 1 Common	1.76	9
No. 2 Common	1.60	54
No. 3 Common	1.48	61
No. 4 Common	1.36	42

was determined for each specimen in a group and bending strength was determined for two specimens per group. No correction for shear deflection was deemed necessary because the loading configuration provided for shear-free deflection in the middle third of the span and the span-to-depth ratio was relatively high. The specimens were orientated in the test setup such that face laminations were stressed in compression and back laminations were stressed in tension.

Results

Data obtained from testing of the boards and the laminated planks are presented in the Appendix. Average MOE values for the boards used in this study are summarized in Table 2. Observed MOE values were similar to those reported in the *Wood Handbook* (FPL 2010) for lodgepole pine clear wood (1.34 $\times 10^6$ lb/in^2). The MOE values varied with visual grade. The D Select and No. 1 common grade grouping had an average MOE of 1.76 $\times 10^6$ lb/in^2, and the No. 4 Common grouping had an MOE value of 1.36 $\times 10^6$ lb/in^2. This is in agreement with the known relationship between visual board grade and MOE.

Average specific gravity (SG) and MOE values of the laminated specimens are shown in Table 3. Maximum and minimum bending strength values are also summarized in Table 3. The SG values ranged from 0.394 to 0.404. The published value for SG of lodgepole pine clear wood is 0.41. Average MOE values for the laminated specimens varied from 1.35 to 1.62 $\times 10^6$ lb/in^2.

Of particular significance are MOE and strength values for laminated specimens in the group (D) that used board MOE as the criterion for determining the layup pattern. This group had the lowest SG and highest MOE and strength values. The lowest strength specimen in this group was nearly as strong as or stronger than the specimens of maximum strength in the groups that used visual grade of the boards for determination of layup patterns.

Concluding Comments

Results from this pilot study illustrated that lodgepole pine boards can be used to manufacture a laminated wood product that has mechanical properties greater than those for clear wood of the same species. The results also showed that by using the MOE of the boards as the criterion for determining layup pattern, laminated planks can be made with significantly improved mechanical properties compared with those of the individual boards. MOE is commonly used as a nondestructive test.

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Table 3. Summary of results for the tests conducted on the laminated plank specimens

Group	Board MOE[a] ($\times 10^6$ lb/in^2)	Properties of laminate: MOE[a] ($\times 10^6$ lb/in^2)	Specific gravity	Number of specimems	MOR (lb/in^2) Maximum	MOR (lb/in^2) Minimum
A	1.45 (0.302)	1.35 (0.194)	0.394	10	3,920	3,690
B	1.47 (0.391)	1.39 (0.190)	0.396	10	5,650	3,650
C	1.55 (0.322)	1.52 (0.154)	0.404	10	5,570	4,280
D	1.53 (0.310)	1.62 (0.144)	0.391	20	7,500	5,300

[a]Values in parentheses are standard deviations.

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Appendix—Data from Test Results

Table A1. Load and deflection data from testing of lodgepole pine boards and laminated planks

Group	Specimen	MOE of board ($\times 10^6$ lb/in^2) Face	Center	Back	MOE of plank ($\times 10^6$ lb/in^2)	MOR of plank[a] (lb/in^2)
A	1	1.07	1.54	1.62	1.41	
	2	1.36	1.48	1.69	1.25	
	3	0.92	1.84	1.91	1.32	
	4	1.70	1.33	1.29	1.37	
	5	1.59	0.88	1.56	1.02	3,690
	6	1.27	1.19	1.78	1.32	
	7	1.12	1.03	1.21	1.17	
	8	2.02	0.95	1.74	1.75	3,920
	9	1.61	1.41	1.68	1.30	
	10	1.68	1.29	1.62	1.59	
B	1	2.24	1.54	1.47	1.64	5,650
	2	1.16	1.30	1.33	1.28	
	3	1.61	1.09	1.72	1.60	
	4	1.63	1.54	0.77	1.15	
	5	1.82	1.69	1.10	1.38	
	6	1.34	2.22	1.26	1.41	
	7	1.40	1.95	0.98	1.08	3,650
	8	2.20	1.26	1.10	1.54	
	9	0.87	1.69	1.95	1.22	
	10	1.73	1.18	1.05	1.58	
C	1	2.14	1.64	1.43	1.70	
	2	2.08	1.35	1.47	1.74	5,570
	3	1.88	1.30	1.58	1.62	
	4	1.34	0.97	1.48	1.22	4,280
	5	2.11	1.55	1.01	1.46	
	6	1.17	1.30	1.72	1.50	
	7	2.09	1.47	1.20	1.47	
	8	1.70	1.38	1.10	1.53	
	9	1.81	1.69	1.95	1.64	
	10	1.61	1.73	1.31	1.33	
D	1	1.71	0.99	1.67	1.77	
	2	1.29	0.95	1.73	1.67	
	3	2.01	1.01	1.70	1.87	
	4	1.69	1.36	1.49	1.52	
	5	1.83	1.17	1.31	1.73	
	6	2.28	1.08	1.37	1.52	
	7	1.83	1.34	1.50	1.73	
	8	1.91	1.37	1.47	1.45	
	9	1.80	1.33	1.55	1.84	
	10	1.77	1.33	1.32	1.52	
	11	2.19	0.90	1.61	1.49	
	12	1.83	1.10	1.53	1.87	7,500
	13	–	–	–	1.55	
	14	–	–	–	1.38	
	15	1.99	1.22	1.44	1.58	
	16	1.67	1.08	1.35	1.58	
	17	1.84	1.30	1.79	1.73	
	18	1.83	1.39	1.46	1.63	
	19	1.74	1.07	1.36	1.50	
	20	1.84	1.21	1.57	1.10	5,300

[a]Only two specimens were tested to failure. Therefore, only two MOR values are reported per group.