USDA Forest Service Research Paper RM-62 October 1970

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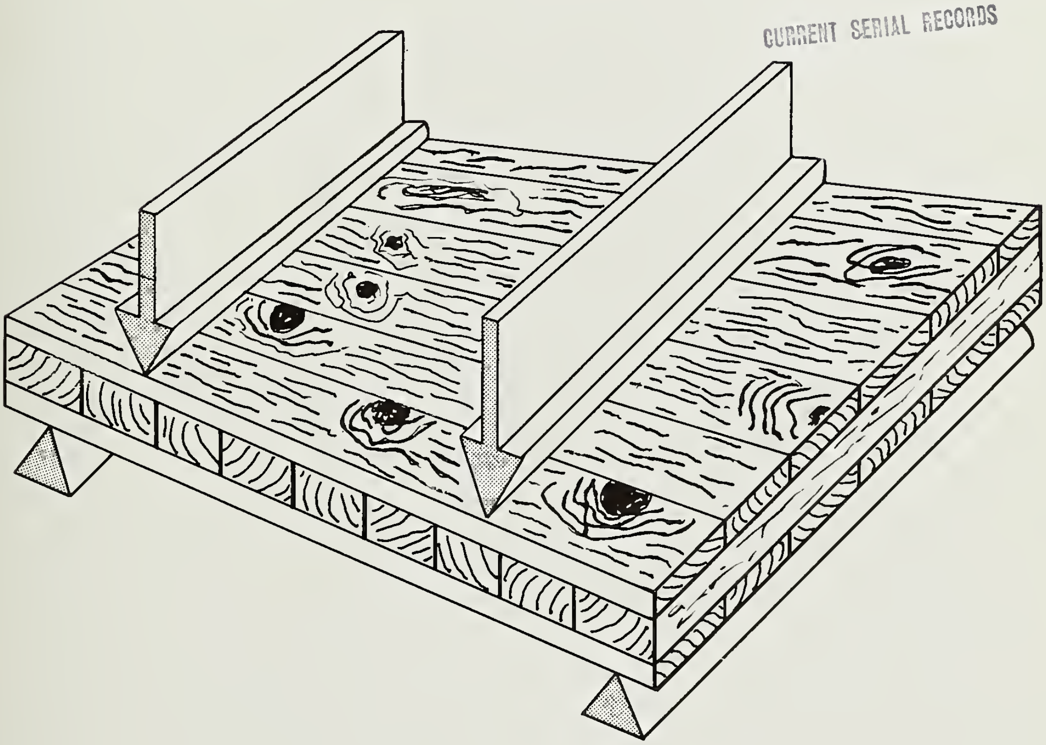

Rocky Mountain Forest and Range Experiment Station
U. S. Department of Agriculture Forest Service
Fort Collins, Colorado

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by

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ABSTRACT

Glued lumber decking panels fabricated with Grade 3 Common faces and 4 Common cores are as stiff or stiffer than conventional panelized decking designed for 4-foot spans. Only panels fabricated with Grade 1 and 2 Clear faces can be thinner or span a greater joist spacing than those with 3 Common faces and 4 Common cores.

Key Words: Panels, lumber, forest products, *Pinus ponderosa*.

Contents

Acknowledgments

This study was conducted in cooperation with the South Dakota School of Mines and Technology, Rapid City, South Dakota, and through collaboration of the U. S. Forest Products Laboratory, Madison, Wisconsin.

Forest Products Laboratory scientists assisting were: Bruce G. Heebink, on original concept and design of the panel; M.L. Selbo, on fabrication technique; and Edward W. Kuenzi and Billy Bohannan, on engineering design and tests.

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Introduction

Panelizing laminated decking shows considerable promise for utilizing low-grade lumber from ponderosa pine (Pinus ponderosa Laws.) and other species, and for recovering some of the lost sheathing market. This product can be designed for specific stiffness and strength requirements, can be manufactured into panel form for reduced installation costs, and could utilize large amounts of low-grade lumber. Lower grades of lumber, with lower moduli of elasticity and rupture, can be used as core material, with higher grades of lumber resawn for the outer plies (fig. 1).

Figure 1.--Test panel with resawed 4/4 lumber faces glued perpendicularly to the nominal 1-inch core boards.

The purpose of this study was to provide design information for laminated decking of Black Hills ponderosa pine lumber. The primary objective was to determine and compare both stiffness and ultimate load-carrying capacity of decking fabricated with different lumber grades.

It has been established that moisture content, density, knots, cross grain, shakes, checks, borer holes, wave, and decay affect the bending strength of wooden members.[2] The most frequent and important strength-reducing defects in the lower common grades are knots. The modulus of rupture and modulus of elasticity are reduced by the lower compressive and tensile strength of the knot, associated cross grain, and by stress concentrations bordering the knot.

Methods

Fabricating the Panels

Rough air-dried 1- by 6-inch ponderosa pine boards, with defect types, sizes, and distributions representative of the lumber grades to be used in the test panels, were selected by a lumber grader at Black Hills sawmills. Forty test panels, 10 for each lumber face and core combination, were fabricated in the following combinations:

Faces	Cores
3 Common	4 Common
2 Common	4 Common
1 & 2 Clear	4 Common
1 & 2 Clear	1 & 2 Clear

[2] Markwardt, L. J., and Wood, L. W. Simplified principles for structural grading of timber. USDA Forest Serv., Forest Products Lab. Rep. 2112, 19 p., illus. 1958.

No decay or open defects greater than 1/16 inch in width were allowed in any member except those permitted on grade 4 Common. The moisture content of the rough 4/4 lumber, measured with an electric moisture meter on 10 randomly selected boards within each grade, averaged 11.5 percent and ranged from 10 to 13 percent. Stress distribution was sampled with three 1-inch sections sawed from three randomly selected boards within each lumber grade. The prong-type stress specimens indicated very little or no detectable stress within the sample boards.

The rough lumber for face boards was resawn with a vertical line bar resaw, jointed on one edge and ripped on the other edge to 5½-inch widths, and crosscut to 50-inch lengths (fig. 2). The rough lumber for core boards was planed on both faces to 25/32-inch thicknesses, jointed on one edge and ripped on the other edge to 5½-inch widths, and crosscut to 27½-inch lengths. Nine core boards and 10 face boards were randomly selected and arranged for each panel within each lumber face and core combination; upper and lower face boards were oriented at right angles to core boards. The five face boards were stapled together at the ends to facilitate handling and assure tight joints when pressed. The staples were removed when the laminated panel was trimmed to a 48-inch length.

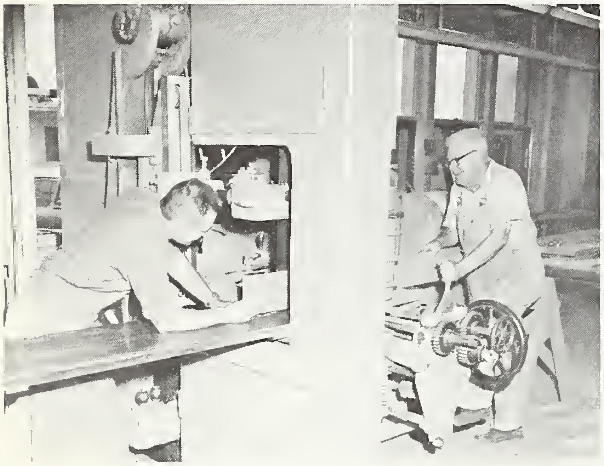

Figure 2.--Resawing rough 4/4 lumber into face boards. The saw was set to produce face boards with 7/16-inch thickness. This was necessary to provide for planing a smooth gluing surface, and having a final uniform thickness of 3/8 inch for all face boards.

Phenol-resorcinol adhesive was spread on both surfaces of the core boards at the rate of 65 to 70 pounds per thousand square feet. Glue was not spread on either the face boards or the edges of the core boards. The panels were pressed at 150 pounds per square inch (p.s.i.) for 6 hours at 80° to 90°F. (fig. 3). The cured panels were planed on both faces to a uniform thickness, and trimmed to a 24-inch width and 48-inch length. The panels were stickered and kept at a moisture content of 11 to 12 percent until tested for strength.

Figure 3.--Five panels were assembled and pressed at one time. Note squeeze out of glue.

Testing the Panels

The panels were statically bent over a 44-inch span with equal loads applied at quarter points (fig. 4). The movable head of the Tinius Olsen 400,000 pound Super L Testing Machine[3] was driven at the rate of 0.34 inch per minute. A Tinius Olsen Model D-2 Deflectometer and Model 51 Recorder measured and recorded loads and corresponding midspan deflections between the supports. A tripoint deflectometer fabricated with plywood, three cap screws, and an Ames gage measured midspan deflection of the constant moment portion of the panel between the load points (fig. 5). A Bolex 16 mm. camera synchronized with a

[3] Trade and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

Sanborn 150 Recorder photographed the Ames gage every second.

The length, width, and thickness of the panels were measured within the ±0.3 percent accuracy stipulated by ASTM for tests of veneer, plywood, and other glued construction.[4] Deflections were measured and recorded to the nearest 0.001 inch.

A 1-inch-wide section sawed across the width of the panel after testing was weighed to the nearest 0.01 gram, ovendried at 103°C., and reweighed to determine the moisture content.

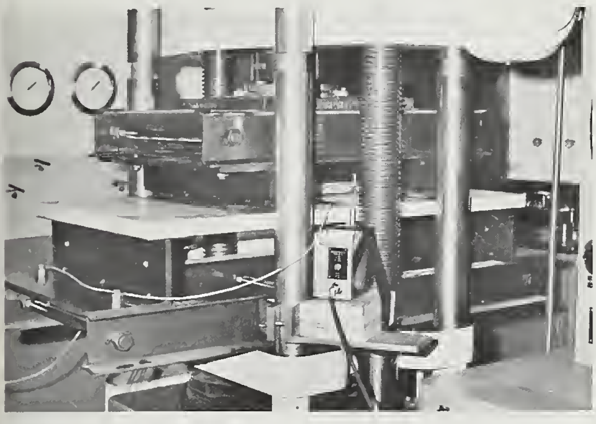

Figure 4.--Test panels were loaded at quarter points, and midspan deflection between supports was measured with a deflectometer. Two 4- by 25-inch stainless steel plates were placed between the panel and each loading edge of the static bending tool. Graphite was spread between the plates to allow easy movement.

Results

Strength of Panels

Perhaps the most significant results were that the panels with grades 2 Common faces and a 4 Common core were neither significantly stronger nor stiffer than those with grades 3 Common faces and a 4 Common core (table 1). Also panels with grades 1 and 2 Clear faces and with a 1 and 2 Clear core, while stronger than those with a 4

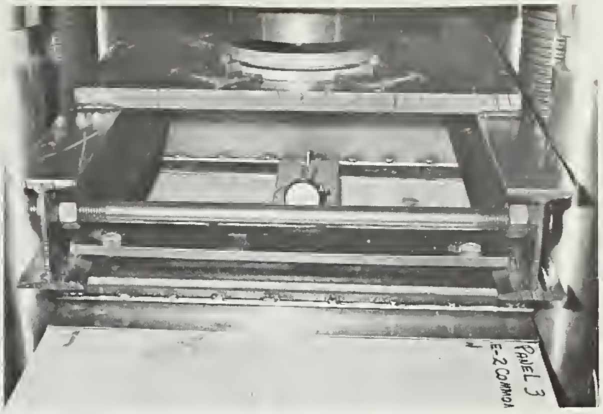

Figure 5.--Tripoint deflectometer located between load points to measure deflections for calculating modulus of elasticity, excluding shear.

Common core, were not significantly stiffer. As might be expected, the panels with grades 1 and 2 Clear faces and with either a 1 and 2 Clear or a 4 Common core were stronger and stiffer than those with either 2 or 3 Common faces and a 4 Common core. The between-panel variation of both strength and stiffness was greatest for the 3 Common face and 4 Common core combination.

Table 1.--Strength and stiffness of panels with different lumber grades in the faces and cores[1]

Lumber grade		Modulus of rupture[2]	Modulus of elasticity[1]	
Faces	Cores		Including shear	Excluding shear
		p.s.i.	× 10^6 p.s.i.	
1&2 Clear	1&2 Clear	9150 ± 500	1.45 ± 0.06a	1.61 ± 0.07a
1&2 Clear	4 Common	8100 ± 380	1.40 ± 0.04a	1.55 ± 0.06a
2 Common	4 Common	5790 ± 620a	1.25 ± 0.05b	1.38 ± 0.08b
3 Common	4 Common	5310 ± 810a	1.17 ± 0.07b	1.33 ± 0.10b

[1] Grade combinations with same letter are same--(5 percent) Duncan's multiple range test.

[2] 95 percent confidence limit.

The average and range of certain test variables are shown in table 2. The height and width values are each averaged from six measurements within the constant moment portion of each beam. The average specific gravity based on total panel weight and volume for all panels was 0.46, greater than

[4] *American Society for Testing and Materials. Standard methods of testing veneer, plywood,and other glued veneer constructions, ASTM Designation: D 805-63, p. 218-221. In 1966 Book of ASTM Standards, Part 16, Structural Sandwich Constructions; Wood; Adhesives. Philadelphia, Pa.: Amer. Soc. Test. Mater. 1966.*

Table 2.--Average and range of measured or calculated variables for four tests of panel construction

Construction of test panels	Thickness	Width	Moisture content (ovendry weight)	Specific gravity	Stiffness: Including shear strain $(EI)_1$	Stiffness: Excluding shear strain $(EI)_2$	Ultimate load
	Inches	Inches	Percent		(Lb.-inch²/inches of width)×10³	(Lb.-inch²/inches of width)×10³	Pounds
Faces--1&2 Clear Core --1&2 Clear							
Average	1.441	24.02	10.4	0.47	307	340	11,700
Range	1.433 to 1.445	24.00 to 24.03	9.5 to 11.2	0.45 to 0.48	287 to 336	312 to 371	10,000 to 13,100
Faces 1&2 Clear Core --4 Common							
Average	1.442	24.02	10.9	0.46	297	329	10,400
Range	1.400 to 1.443	24.00 to 24.03	10.2 to 11.4	0.44 to 0.47	278 to 317	299 to 357	9,350 to 11,800
Faces--2 Common Core --4 Common							
Average	1.439	24.01	11.3	0.44	262	289	7,370
Range	1.436 to 1.441	23.98 to 24.02	10.9 to 11.6	0.44 to 0.45	237 to 291	241 to 305	6,300 to 10,000
Faces--3 Common Core --4 Common							
Average	1.440	24.01	10.9	0.46	247	280	6,800
Range	1.437 to 1.441	23.98 to 24.03	10.4 to 11.4	0.44 to 0.48	218 to 287	241 to 323	5,130 to 9,800

the 0.41 value for ponderosa pine at 12 percent moisture content in the Wood Handbook.[5]

Strength Formulas

The formulas to calculate stiffness and the moduli of elasticity and rupture are:

STIFFNESS:
Including shear strains—

$$(EI)_1 = \frac{P_1 A}{48\Delta_1}(3L_1^{\,2} - 4A^2)$$

where

$(EI)_1$ = stiffness including shear strains, pounds-inch²
P_1 = load within proportional limit of beam, pounds
A = distance from support to load point, inches
L_1 = span length between supports, inches
Δ_1 = deflection produced at midspan relative to supports by P_1, inches

[5] U. S. Forest Products Laboratory. *Wood Handbook*. U. S. Dep. Agr., Agr. Handb. 72, 528 p. 1955.

Excluding shear strains—

$$(EI)_2 = \frac{P_2 A L_2^{\,2}}{16\Delta_2}$$

where

$(EI)_2$ = stiffness excluding shear strains, pounds-inch²
P_2 = load within proportional limit of beam, pounds
A = distance from support to load point, inches
L_2 = span length within constant moment section over which deflection was measured, inches
Δ_2 = deflection produced at midspan of L_2 by load, P_2, inches

MODULUS OF ELASTICITY:
Including shear strains—

$$E_{f_1} = \frac{(EI)_1 - E_{c_1} \cdot I_c}{I_f}$$

where

E_{f_1} = modulus of elasticity of faces (parallel to grain), p.s.i.
I_f = moment of inertia of face plies, inches⁴
E_{c_1} = modulus of elasticity of core (perpendicular to grain), assumed to be 0.05 E_{f_1}, p.s.i.
I_c = moment of inertia of core, inches⁴
$(EI)_1$ = value from test data

Excluding shear strains—

$$E_{f_2} = \frac{(EI)_2 - E_{c_2} \cdot I_c}{I_f}$$

where

E_{f_2} = modulus of elasticity of faces (parallel to grain), p.s.i.
I_f = moment of inertia of face plies, inches^4
E_{c_2} = modulus of elasticity of core (perpendicular to grain) assumed to be $0.05E_{f_2}$, p.s.i.
I_c = moment of inertia of core, inches^4
$(EI)_2$ = value from test data

MODULUS OF RUPTURE:

$$MOR = \frac{M_b \cdot C}{\left[\frac{T^3 - 0.454}{12}\right] W}$$

where

MOR = modulus of rupture
M_b = maximum bending moment, inch-pounds
C = distance from neutral axis to extreme fiber, inches
T = thickness of panel, inches
W = width of panel, inches

Most of the panels failed suddenly with no visible compression failure.

The load-deflection curves were linear to failure, which indicated sudden tension failure and little or no compression failure. Compression failure was apparent on only three of the panels.

Conclusions

An important conclusion from this study is that stiffness of panels fabricated with 3 Common faces and 4 Common cores is as high or higher than conventional panelized decking designed for 4-foot spans. The measured stiffness (EI) of the 10 test panels averaged 247,000 and ranged from 218,000 to 287,000 pounds-inch^2 per inch of width. The maximum bending moment of the 10 test panels averaged 1560 and ranged from 1170 to 2240 inch-pounds per inch of width.

A second conclusion is that only panels fabricated with grade 1 and 2 Clear faces can be thinner or span a greater joist spacing than those with 3 Common faces and 4 Common cores. Theoretically, the lumber grade of the faces, not that of the core, affects both stiffness and the maximum bending moment the most. The ratio of the moment of inertia of the face section to that of the core of a 1.441-inch-thick panel with a 0.781-inch core is calculated at 5.3:1.

This strength data will help a design engineer to determine working stresses when using this type of panel.

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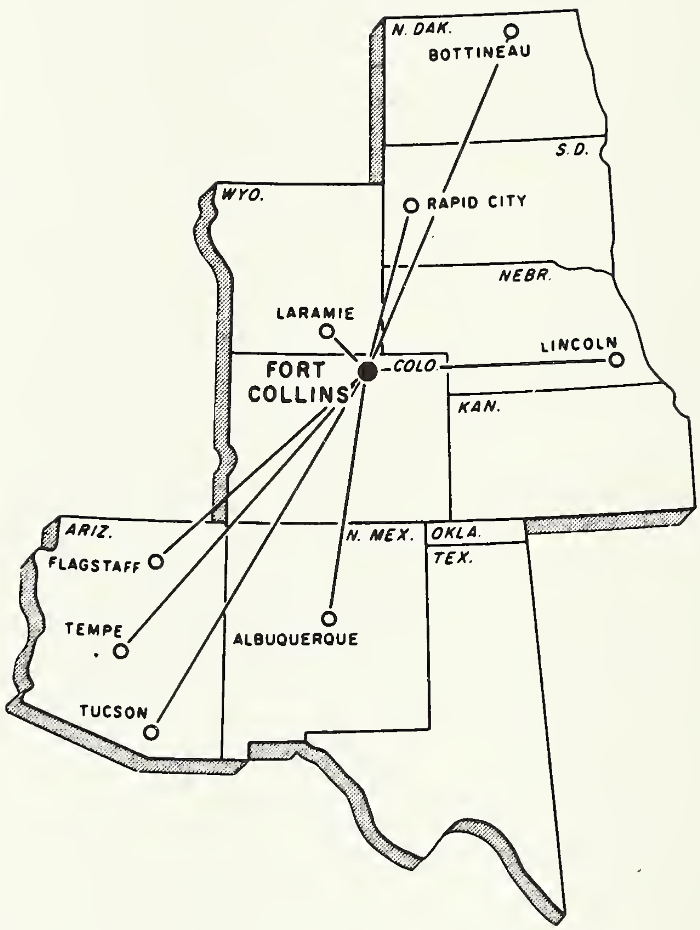
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