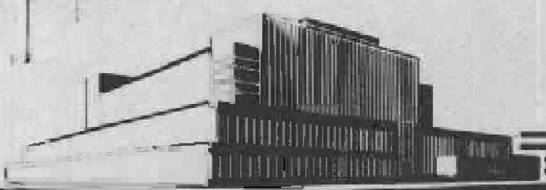
MECHANICAL PROPERTIES OF COULTER PINE FROM CALIFORNIA

No. 2102

January 1958

INFORMATION REVIEWED
AND REAFFIRMED
1965



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

MECHANICAL PROPERTIES OF

COULTER PINE FROM CALIFORNIA

By

A. W. DOHR, Engineer

Forest Products Laboratory,[1] Forest Service
U. S. Department of Agriculture

Summary

Coulter pine (Pinus coulteri) as represented by a sample from Riverside County, California, is a soft, lightweight, reddish brown, coarse-grained wood that has strength properties comparable to those of ponderosa and Jeffrey pine, two species with which it grows and which it resembles in general appearance.

Because the sample was small, it was necessary to use nonstandard procedures for cutting and matching test specimens. Because of the comparatively uniform growth rate, as evidenced by the width of growth rings in a cross section of the tree, the use of nonstandard procedures is believed to have had minimum effect upon the average strength results, and these data can be considered reasonably representative of the species.

Introduction

Although Coulter pine is a smaller tree, it remotely resembles in general appearance young or middle-aged ponderosa pine. It can, however, be easily distinguished by its stiffer, much heavier foliage, longer needles somewhat grayish-green in color, stouter twigs, and huge cones with sharp, hooked bracts.

The area of growth of Coulter pine is limited to the mountains of west, central, and southern California, northern Lower California, and elsewhere in Mexico. It grows from an elevation of a few hundred feet above sea level on the north slope of Mount Diablo, near Oakland, to about 6,000 feet in the San Bernardino mountains. It is also known locally as pitch pine, nut pine, and big cone pine. In California, it is considered one of the fastest growing

---

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

pines, although it is quite limby and relatively short lived. The clear trunk is often not over 10 to 15 feet long; total height ranges from 40 to 60 feet with trees occasionally more than 75 feet. At breast height, the diameter of mature trees is usually 18 to 30 inches but on occasion may be as large as 3-1/2 feet.

In southern inland mountains, Coulter pine has endured almost arid conditions with long droughts and rapid summer evaporations. Generally, it is found on dry, warm slopes or ridges and sometimes on more moist sheltered north slopes. It is a persistent periodic seeder, but seed germination is only moderate. Reproduction is never dense and never in pure stands.

The bark of Coulter pine becomes rough and broken, even in young trees. It later becomes deeply furrowed and ridged and of a very dark or blackish-brown color. Leaves, 3 to a bundle, are 7-1/2 to 12 inches long and average about 9 inches. Cones are extremely large and heavy and distinguish this pine from its relatives or associates.

Lower branches are long, often bend downward to the ground, and have an upward curve at their ends. Numerous bunches of erect stiff leaves conceal their extremities.

Current interest in the properties of Coulter pine stems from its use as a parent species in hybridization. Coulter pine is more resistant to attack by the pine reproduction weevil than other western pines. It will be of interest to determine to what extent that characteristic is imparted to hybrids and to what extent the structural and property characteristics of the parent are carried over into crosses between Coulter pine and other species.

Material

A sample of Coulter pine (shipment 1690) was obtained from the San Bernardino National Forest in Riverside County, Calif., in cooperation with the California Forest and Range Experiment Station early in 1955. One 36-inch bolt was cut from each of 5 tree trunks at points equivalent to heights of from 13 to 22 feet above the ground.

The trees had grown at an elevation of 4,600 to 5,300 feet in mountainous country where the annual rainfall was estimated at 28 inches and the mean annual temperature as 51.5° F. In addition to herbarium samples for identification purposes the information in table 1 was provided.

The trees represented a considerable range in growth conditions and characteristics. According to information received from the California Experiment Station, tree No. 1 was a fresh, green tree with limbs to the ground. Tree No. 2 was down but alive, with limbs also to the ground. Both of these trees were infested with bark beetles and were cut as part of a bug control operation. Tree No. 3 was infested with bugs, had been alive when felled the previous year, and was taken from a stand in which some trees were killed in a fire during 1943. Both trees Nos. 4 and 5 were limby. Tree No. 5 was fire-killed in September 1953 and had grown with a slight sweep.

The standard heights for bolts usually used for property comparisons are 8 to 16 feet. All of the bolts in this study were cut from the logs at heights slightly above that level (table 1).

Test Procedures

Short lengths, comparatively small cross sections, and the presence of numerous knots associated with low limb growth prohibited the preparation of specimens of a size and distribution corresponding to standard practices.[2] A method of selecting specimens was devised whereby end-matched specimens used for tests of static bending and compression parallel to grain were prepared in the 1- by 1-inch cross section utilized in the secondary standard procedure covered by the ASTM standards.[2] Standard sizes were maintained for the other tests. No tests of impact strength or tensile strength parallel to grain were made.

Each bolt was ripped into test sticks in accordance with standard practices.[2] This provided pairs of 2-1/2-inch-square sticks in 4 directions from the pith. These pairs were numbered consecutively from pith to bark in each direction. These directions were designated H, K, L, and M.

Tests of green material were made on sticks oriented in the H-L direction, and tests of air-dry material on sticks in the K-M direction. This provided good matching for the two moisture conditions in outer pieces, but no material was available from the immediate pith area for dry tests.

The following tests were made on each ring-matched pair of sticks.

Test	Specimen size Inches
Static bending	1 by 1 by 16
Compression parallel to the grain	1 by 1 by 4
Toughness (radial and tangential)	0.79 by 0.79 by 11
Compression perpendicular to grain	2 by 2 by 6
Hardness	2 by 2 by 6
Shear (radial and tangential)	2 by 2 by 2-1/2
Cleavage (radial and tangential)	2 by 2 by 3-3/4
Tension perpendicular to grain (radial and tangential)	2 by 2 by 2-1/2

---

[2]Standard Methods of Testing Small Clear Specimens of Timber. Designation D143-52, American Society for Testing Materials.

Specimens for volumetric shrinkage represented one-half of the pairs in the green material. Pieces for radial and tangential shrinkage tests were taken from the quarters remaining after removal of the original flitches. These sections were sometimes large enough to permit a single pair of specimens from each of the four quarters to be obtained for radial and tangential shrinkage tests. Other trees produced fewer specimens, and tree 1 provided none.

Tests of green material were made immediately, and moisture contents averaged well above 100 percent. Air-dry material for testing was initially exposed to covered outside drying conditions and finally to controlled temperature and humidity. Seasoning progressed very slowly in the later stages, and tests of dry material were eventually completed after more than a year of seasoning.

Test methods used were in accordance with standard procedures,[2] and the results are directly comparable with standard tests of other species provided proper consideration is given to the method of selecting specimens and to the tree heights represented.

Test Results

Test results are presented in table 2 for material considered clear and sound. The data included tests of a few pieces from pith areas that were of a rubbery nature and somewhat low in both modulus of rupture and crushing strength when considered in relationship to density. Some specimens were rejected because of cross grain, and the pith area of tree 2 was discarded because of decay. Knots were present in some pieces where they did not influence test values other than the calculations for specific gravity.

Fewer air-dry tests were conducted, since specimens in the pith area were tested in the green condition. A fair representation was obtained for shear tests, but the number of cleavage and tension perpendicular to the grain specimens was seriously reduced because of shortage of material. This results in a poor comparison both for the two conditions of seasoning and for radial and tangential relationships in these two types of tests.

Toughness tests brought out two pronounced material characteristics -- cross grain and brittleness. In the 17 pairs of specimens prepared for testing in the air-dry condition, it was necessary to discard 10 pieces that failed at an angle in a single split as a result of excessive slope of grain. A generally brash condition was exhibited in acceptable test specimens, where many specimens broke abruptly at the center into two separate pieces, while others barely hung together at the point of rupture. Tree 5 produced only two good tests in the dry condition, both specimens were loaded on the radial side.

Direct comparison of the toughness of Coulter pine and other species is limited by the fact that relatively few toughness tests have been made on specimens of the present standard 0.79- by 0.79-inch cross sectional size. However, comparable tests of a ponderosa pine sample from the Black Hills of South Dakota have recently been made, and the average values from these tests are included in table 2 for comparison. It may be seen that, despite the brittle appearing fractures obtained in Coulter pine, the average toughness was about the same as that of ponderosa pine. Toughness is strongly affected by differences in specific gravity. Both the Coulter pine and ponderosa pine have relatively low specific gravity; therefore, the total toughness can be expected to be low in comparison with denser species. On the other hand, both species appear to have at least as high toughness values, on the average, as would be expected from their density.

Average strength values for other properties of ponderosa and Jeffrey pine have also been included in table 2 for comparative purposes. There appears to be little difference in the three species in the green condition with respect to specific gravity and shrinkage characteristics. The average specific gravity at 12 percent moisture content is somewhat higher for Coulter pine than for the other 2 species. This slight difference may possibly reflect the method of test selection, since there was no sample included of air-dried Coulter pine obtained from the pith area, which is usually of below average density.

Past experience indicates that the values obtained from Coulter Pine are probably slightly lower than if the specimens had been taken at the standard height. The possible reduction in specific gravity and strength properties that might be expected in comparison with the ponderosa and Jeffrey pine values listed in table 2 is considered negligible, however, in relation to differences that may occur due to specimen size and matching effects.

Values for static bending and compression parallel to the grain compare favorably in most cases for the three species, except that stress at proportional limit is noticeably lower for Coulter pine in both types of tests. This deficiency is believed to result from somewhat more refined testing techniques used in modern testing rather than from a basic difference in the strength of the material. In tests of compression perpendicular to the grain, the lower average values may be associated with the smaller trees used in the tests of Coulter pine, which would cause a larger proportion of the pieces to have annual rings at a substantial angle with respect to the applied load. Such a condition is known to reduce test values.

Hardness and shear values for the 3 species were not greatly different, except that shear tests of the air-dried Coulter pine yielded substantially higher values than were obtained from the other 2 species.

Markedly lower values in cleavage and tension perpendicular to the grain were obtained for seasoned Coulter pine than for green material of that species. Lack of material for these two types of tests prevented a fully representative selection of specimens. The tests of air-dry material were especially limited in number. For this reason, and because of poor matching between green and dry test material, the listed values for dry tests are not considered a reliable average for the species.

Longitudinal shrinkage.--A few measurements of longitudinal shrinkage of Coulter pine were also made. From pieces representing the entire cross section of trees 3 and 5, except near the pith, the following was determined: Tree No. 3 -- twelve pieces: Range -- 0.126 to 0.190 percent, average -- 0.155 percent. Tree No. 5 -- nine pieces: Range -- 0.148 to 0.232 percent, average -- 0.185 percent. For material from a few scattered areas nearer to the pith of the other trees, the following individual values for longitudinal shrinkage were found: 0.220, 0.222, 0.250, 0.280, 0.318, and 0.320 percent.

Material with longitudinal shrinkage of more than 0.30 percent will generally cause serious warping and crooking when in the same board with material of lower shrinkage. Wood in the outer parts of the Coulter pine bolts would not be expected to cause difficulty from excessive longitudinal shrinkage. The area showing relatively high longitudinal shrinkage was near the pith, where quality was already reduced by the presence of numerous knots and, in some cases, by decay.

It was also noted that specimens selected from inner parts of the tree cross sections for bending and compression tests yielded somewhat lower values for modulus of rupture and maximum crushing strength than would be expected from observing their specific gravity.

Conclusions

Any classification of the mechanical properties of Coulter pine based on the values here presented should be made only after proper consideration is given to the method of selecting material and specimens. The representation of material used for the tests was considerably different than the standard practice; the short lengths, the comparatively small cross sections, and the abundance of knots and associated grain distortions restricted the number and types of tests that could be made.

The results presented are from clear material tested in accordance with standard test procedures.

On the basis of these limited data, it would appear that the shrinkage, specific gravity, and strength properties of Coulter pine are not greatly different from those of ponderosa and Jeffrey pine.

Appendix

Jeffrey-Coulter Pine Hybrid

In 1948, the Forest Products Laboratory investigated some characteristics of a Jeffrey-Coulter pine hybrid. Included were tests of specific gravity and radial, tangential, and longitudinal shrinkage on specimens cut from 2 full cross sections taken from points equal to heights of 16 and 32 feet in a tree grown in the San Bernardino National Forest, 110 miles east of Los Angeles, Calif.

Because that test material represented a natural hybrid of two of the species for which values are shown in table 2, the average results are of interest and are presented here.

Specific gravity (based on volume when green and weight when ovendry).--Range; 0.36 to 0.43, average 0.40.

Shrinkage.--Tangential; range 5.6 to 7.2 percent, average 6.7 percent. Radial; range 3.5 to 4.9 percent, average 4.3 percent. Longitudinal; range 0.23 to 0.49 percent, average 0.34 percent. The differences between average values for the two heights examined were not great.

Table 1.-- Preliminary data for sample of Coulter pine collected in 1955 in Riverside County, California

Tree No.	Age	Diameter at breast height	Total height	Merchantable length	Height of sample above ground
	Years	Inches	Feet	Feet	Feet
1	70	17	52	16	13 to 16
2	75	23	70	32	14 to 17
3	114+	36	94	65	19 to 22
4	48	20	58	16	16 to 19
5	62	23	85	48	19+ to 22+

Table 2.--Strength and related properties of Coulter pine (Pinus coulteri)

(Shipment 1690, Riverside County, Calif.)

Tree No.	Bolt No.	Moisture content	Specific gravity, oven-dry, based on volume -- At test	Specific gravity -- When oven-dry	Shrinkage from green to ovendry condition based on dimensions when green -- Volumetric	Shrinkage -- Radial	Shrinkage -- Tangential	Static bending -- Stress at proportional limit	Static bending -- Modulus of rupture	Static bending -- Modulus of elasticity	Static bending -- Work -- Proportional limit	Static bending -- Work -- Maximum load	Compression parallel to grain -- Stress at proportional limit	Compression parallel to grain -- Modulus of elasticity	Compression parallel to grain -- Maximum crushing strength	Compression perpendicular to grain -- stress at proportional limit	Hardness load required to embed a 0.444-inch ball to 1/2 its diameter -- End	Hardness -- Side	Shear parallel to grain -- maximum shearing strength	Cleavage -- load to cause splitting	Tension perpendicular to grain -- maximum tensile strength	Toughness (0.79 inch x 0.79 inch x 11.00 feet) -- Radial	Toughness -- Tangential
		Percent			Percent	Percent	Percent	P.s.i.	P.s.i	1,000 p.s.i	In.-lb. per cu. in.	In.-lb. per cu. in.	P.s.i.	1,000 p.s.i.	P.s.i.	P.s.i.	Lb.	Lb.	P.s.i.	Lb. per in. of width	P.s.i.	In.-lb. per specimen	In.-lb. per specimen
											GREEN												
1	d	140.4	0.370	0.414	9.4	.....	.....	2,760	5,150	1,086	0.39	5.11	1,800	1,120	2,290	186	381	326	664	156	266	170.8	203.1
2	d	139.0	.386	.443	9.0	3.36	6.03	2,280	4,890	850	.34	6.32	1,360	907	2,260	194	335	334	646	158	212	208.4	266.4
3	f	75.3	.400	.442	10.4	3.84	6.65	2,680	4,990	1,122	.36	4.89	1,510	1,258	2,370	245	364	308	710	158	237	137.6	222.6
4	e	196.6	.364	.403	8.5	3.51	5.68	2,560	4,710	896	.44	6.35	1,250	865	2,090	205	322	316	688	180	336	221.2	296.7
5	f	189.2	.352	.401	10.4	3.53	6.67	2,380	4,560	976	.32	4.73	1,570	1,124	2,080	199	295	283	624	169	246	212.7	253.2
Average		148.1	.374	.421	9.5	3.56	6.26	2,530	4,860	986	.37	5.48	1,500	1,055	2,220	206	339	314	666	162	259	190.1	248.4
											AIR DRY												
1	d	13.4	.419	.....	.....	.....	.....	7,160	11,000	1,491	1.92	13.22	3,740	1,672	5,940	549	698	501	1,454	115	240	113.4	218.8
2	d	13.6	.397	.....	.....	.....	.....	4,490	9,430	1,229	.93	8.72	2,490	1,246	5,030	532	594	436	1,292	90	196	161.5	167.7
3	f	13.0	.424	.....	.....	.....	.....	5,660	10,460	1,595	1.14	9.34	3,080	1,632	5,220	533	586	497	1,395	97	196	151.7	176.9
4	e	13.1	.424	.....	.....	.....	.....	3,880	9,360	1,230	.68	13.79	2,180	1,194	4,620	475	546	466	1,402	109	221	137.2	170.0
5	f	12.8	.388	.....	.....	.....	.....	5,640	9,210	1,456	1.23	8.15	3,200	1,506	4,780	438	479	398	1,237	97	164	141.0	.....
Average		13.2	.410	.....	.....	.....	.....	5,370	9,890	1,400	1.18	10.64	2,940	1,450	5,120	505	581	460	1,356	102	204	141.0	183.4
											ADJUSTED TO 12 PERCENT MOISTURE CONTENT												
		12.0	.413	.....	.....	.....	.....	5,610	10,300	1,428	1.26	11.05	3,150	1,498	5,580	531	617	480	1,421	97	199	.....	.....
											TEST VALUES OF OTHER SPECIES FOR COMPARISON[1]												
											Ponderosa Pine												
		90.9	.379	.450	9.5	3.9	6.3	3,100	5,020	968	.59	5.1	2,070	1,138	2,400	355	300	312	684	167	290	[2]191.1	[2]265.8
		12.0	.402	.....	.....	.....	.....	6,310	9,240	1,262	1.85	6.6	4,060	1,381	5,270	740	554	447	1,165	217	404	[3]146.3	[3]194.8
											Jeffrey Pine												
		101.1	.371	.425	9.9	4.4	6.7	3,170	4,960	982	.60	4.7	2,050	1,128	2,370	353	319	342	694	156	258	.....	.....
		12.0	.401	.....	.....	.....	.....	7,220	9,340	1,241	2.43	6.6	4,240	1,354	5,530	793	613	495	1,207	246	380	.....	.....

[1]Data corresponding to USDA Technical Bulletin 479, "Strength and Related Properties of Woods Grown in the United States." Markwardt and Wilson, 1935.

[2]Toughness tests of Ponderosa pine from Pennington County, South Dakota. Average moisture content 143 percent. Average specific gravity (based on green volume and ovendry weight) 0.380.

[3]Toughness tests of Ponderosa pine from Pennington County, South Dakota. Average moisture content 11.0 percent. Average specific gravity (based on volume at test and ovendry weight) 0.426.

Z M 112 483

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products, and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen
- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.