SOME PROPERTIES OF CALIFORNIA WHITE OAK AND OREGON WHITE OAK

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SOME PROPERTIES OF CALIFORNIA WHITE OAK AND OREGON WHITE OAK

By

BENSON H. PAUL, Forest Products Technologist
ALFRED W. DOHR, Engineer
and
JOHN T. DROW, Engineer

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

Summary

Samples from 4 trees of California white oak (Quercus lobata) averaged 0.59 in specific gravity, based on weight when ovendry and volume when green. The comparable value for white oak (Q. alba) is 0.60. Shrinkage in volume averaged 15.6 percent compared to 15.8 for white oak. Radial shrinkage for both heartwood and sapwood averaged 4.4 percent and tangential shrinkage 10.1 percent. Comparative values for white oak are 5.3 and 9.0 percent. There was a noticeable difference in the magnitude of shrinkage in tangential specimens that were all-sapwood or all-heartwood; the sapwood averaged 8 percent and the heartwood nearly 11 percent.

Longitudinal shrinkage frequently exceeded 0.30 percent of the green dimension, an amount likely to cause trouble in use. In some trees, wood on opposite sides of a trunk had different longitudinal shrinkage values. This indicates that the standing trees were leaning and formed tension wood on one side.

Samples from one Oregon white oak (Q. garryana) tree, older and more slowly grown than the California white oak trees tested, yielded higher average specific gravity and volumetric shrinkage.

California white oak exceeds California black oak (Q. kelloggii) from Butte County, Calif., in average density and strength properties examined, but is

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

inferior to canyon live oak (Q. chrysolepis) from that county. Although somewhat lower in average specific gravity than white oak (Q. alba), it compares favorably with that species in bending properties but is slightly lower in hardness.

Oregon white oak from California was slightly less dense than that previously examined from Douglas County, Oreg. However, in bending it compared favorably, and in hardness it was only slightly inferior.

Introduction

During recent years a market has been sought for certain hardwoods growing in mixture with the predominantly softwood forests of the West. Among these are California white oak (Q. lobata) and Oregon white oak (Q. garryana). Utilization of these species would aid in the silvicultural management of the forests also. No detailed information on properties of California white oak has been available, and only Oregon white oak from Douglas County, Oreg. has been tested.

California white oak grows in western California between the Sierras and the Pacific Ocean southward from the Trinity river. Other names include weeping oak, valley oak, white oak, and California valley white oak.

Oregon white oak ranges from Vancouver Island and southwestern British Columbia through western Washington and Oregon to Marin County, Calif. It is also known as Pacific post oak, white oak, western oak, prairie oak, western white oak, and Oregon oak.

The data reported here include rate of growth, specific gravity, shrinkage, static bending, hardness, and toughness on samples from four trees of California white oak and one of Oregon white oak.

Material

The test samples were selected by the California Forest and Range Experiment Station. Two bolts 3 feet long were taken from each tree, representing two general height levels in the merchantable bole. Exact heights in the trees varied from 6 to 12 feet for the lower and 15 to 28 feet for the upper bolts. The California white oak trees were 71 to 98 years old and 75 to 90 feet in height. Test bolts ranged from 11 to 17 inches in diameter under the bark. The Oregon oak tree was 255 years old and 54 feet tall.

Growth

Growth in diameter of the California white oak trees ranged from fairly rapid when the trees were young to rather slow in the last decades. As measured on the specific gravity specimens, the number of annual rings per inch ranged from 3 to 27 and averaged 12. The one tree of Oregon white oak averaged 34 rings per inch.

Specific Gravity and Shrinkage in Volume

Specific gravity specimens 2 by 2 inches in cross section and 4 inches long were cut from a flitch extending across the section from bark to bark including the pith. There was a large variation in specific gravity within the cross sections of individual trees; the specimens near the pith contained the heaviest wood and those near the bark the lightest. Average differences at the two heights in each tree were not great, as may be seen from table 1.

Specific gravity ranged from a high of 0.76 to a low of 0.45 based on the volume of specimens when green and their weight when ovendry. The average specific gravity of the California white oak was 0.59, which is a little below the average value of 0.60 for white oak (Q. alba).[2] It is possible that the presence of extractives in the heartwood may influence the specific gravity of the heavier specimens in that portion of the trees.

Shrinkage in volume was also determined from the specific gravity specimens. Like specific gravity, shrinkage in volume was variable and, in general, moderately large. Shrinkage in volume of individual specimens ranged from 21.5 percent to 9.3 percent of their green volume. Average shrinkage in volume was 15.6 percent. The heartwood specimens showed greater shrinkage, partly as a result of collapse that was plainly evident. The specimens near the bark, which were mostly or entirely sapwood, shrank less.

Although of very slow growth, the 255-year-old tree of Oregon white oak averaged heavier than the California white oak, its specific gravity being 0.632, and had somewhat higher shrinkage, 17.4 percent.

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[2] Markwardt, L. J., and Wilson, T. R. C. Strength and Related Properties of Woods Grown in the United States. U. S. Dept. Agr. Tech. Bull. 479, 99 pp. illus.

Transverse Shrinkage

Tangential and radial shrinkage specimens were cut from cross-sectional disks 1 inch thick along the grain. The tangential shrinkage specimens measured about 1 inch radially and 2 to 4 inches in the tangential direction. None was taken closer than 2-1/2 inches from the pith because of extreme curvature of rings at that location. Three to six specimens were cut from opposite sides of the pith at each height.

Radial shrinkage specimens were cut from 1-inch cross-sectional disks and were 1 inch tangentially and approximately 4 inches radially. Two to four specimens were taken from each cross section.

Shrinkages were measured progressively at equilibrium with 65 percent and 30 percent relative humidity and when ovendry. Average results are shown in figure 1 and table 2.

Tangential shrinkage of California white oak ranged between 7.08 and 17.70 percent of the green dimension and averaged 10.1 percent. Oregon white oak fell within the above limits and averaged 11.16 percent. There was a sharp difference in tangential shrinkage of heartwood and sapwood specimens. Heartwood specimens of California white oak averaged 10.81 percent and sapwood 8.01. Again, as in the case of volumetric shrinkage, the higher dimensional changes of the heartwood specimens may be attributed at least in part to collapse.

Radial shrinkage of California white oak ranged between 3.36 and 6.97 and averaged 4.43 percent of the green dimensions. Values for Oregon white oak were within the above range, and the average, 4.48, was close to that of the California white oak.

Shrinkage Along the Grain

Longitudinal shrinkage specimens were cut 1 by 1 inch in cross section and approximately 9 inches in length from wood on opposite sides of the pith in each bolt. Three to six specimens were taken from each radius, depending upon availability of clear material.

Shrinkage was measured as drying progressed, at 65 and 30 percent relative humidity and when the wood was ovendry. Total shrinkage was relatively high in many of the individual specimens, and each of the trees contained specimens that shrank more than 0.30 percent. Shrinkage of more than 0.30 percent is considered excessive and likely to cause difficulty from warping of lumber in drying or as a result of moisture changes in use.

The highest longitudinal shrinkage found was 0.714 and the lowest 0.035, the greatest being more than 20 times the least. There was no evidence that heartwood or sapwood affected shrinkage as it did in the case of transverse shrinkage. Unusually high shrinkage values were obtained in both heartwood and sapwood specimens. In most instances, abnormally high longitudinal shrinkage occurred only in the wood on one side of the pith of a given cross section. This indicates the presence of tension wood, probably an influence of leaning trees. In one case, the cellular structure of wood from a specimen having a shrinkage value of 0.694 percent showed an abundance of gelatinous fibers (characteristic of tension wood), while the specimen from the opposite radius with a shrinkage value of 0.094 showed practically none (fig. 2). Such effects of tension wood have been observed in other species. The Oregon white oak likewise yielded a considerable number of longitudinal specimens having unusually high shrinkage.

Strength Tests

Material remaining after specimens for specific gravity and shrinkage were taken was used for a limited number of mechanical tests, including static bending, hardness, and toughness. The bending specimens were of the smaller size (1 by 1 by 16 inches) provided for in the Secondary Method of American Society for Testing Materials Standards,[3] but the 0.79- by 0.79- by 11-inch toughness specimens and 2- by 2- by 6-inch hardness specimens were standard.

The method of selection consisted of cutting one stick for bending tests from each inch of radius, numbered successively from bark to pith, from a flitch ripped from bark to bark through each tree pith. To avoid duplicate representation, only the odd-numbered pieces from one side of the pith and the even-numbered pieces from the opposite side were taken. Toughness specimens were prepared in pairs for radial and tangential testing, on the same basis of representation, with the immediate pith area eliminated because of the removal of that portion of the flitch for bending tests. Two hardness-test pieces were selected from each bolt, one representing the area near the bark and the other as near the pith as possible.

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[3] ASTM Designation D143-52, "Standard Methods of Testing Small Clear Specimens of Timber."

Standard testing practices[3] were observed throughout, except for the method of selection, and the results are essentially comparable with previous tests. Since the total work in static bending on specimens 1 inch in cross section is not directly comparable to values obtained in the more commonly used standard 2-inch size, values for total work were not obtained in these tests. The effect of tree height is not readily evaluated in these tests, since the same bolts are not represented for each tree.

Test Results

Test results for static bending are presented in table 3, and those for hardness and toughness in table 4. Additional observations and comments on the test results are summarized in the following sections.

Static Bending

In California white oak, the average for lower bolts slightly exceeds that for upper bolts in both specific gravity and strength properties, as would be expected, while in Oregon white oak the influence of height in the one tree tested is reversed, with the upper bolt showing superiority (table 3). Although the differences are not great, they indicate the desirability of identical bolt representations for comparative purposes.

In both species, the lightest wood and lowest test values were found in the slowly-grown wood near the bark.

Modulus of rupture and modulus of elasticity showed considerable variation from bark to pith. With the exception of a few scattered areas and some pieces near the pith, however, these properties generally decreased from the pith area toward the bark. An exception to this tendency was found in the lower bolt of tree 4, where modulus of rupture consistently increased in locations nearer the bark except for the outermost piece. Modulus of elasticity was variable across the same area.

The specific gravity of pieces near the pith of both bolts of Oregon white oak was comparatively high. With the exception of one stick from a lower bolt, strength was also high. The exceptional piece was unusually low in both strength and stiffness, exhibiting a rubbery condition often associated with the presence of tension wood.

The relation of modulus of rupture to specific gravity was reasonably consistent in most sticks for both species, but that of modulus of elasticity to specific gravity was more variable.

In both modulus of rupture and modulus of elasticity, Oregon white oak was consistently inferior to California white oak when specific gravity was taken into account.

Hardness

On the basis of average values, the specimens from the outer zone of tree cross sections were less dense and softer than those obtained from inner pieces (table 4). This applies to both species and both tree heights examined from each tree.

In specific gravity the lower bolts averaged slightly higher than the upper bolts, but hardness values in California white oak were not always consistent with that relationship.

In Oregon white oak, the averages for both specific gravity and hardness were highest for the lower bolt.

Toughness

Numerous toughness-test specimens were rejected, chiefly because of excessive slope of grain. Pieces from the outer zone of the log generally were lower in toughness than inner-zone pieces, exhibiting a rather brittle type of failure in comparison with the more common splintering failures of the inner pieces (table 4).

The need for rejection of a relatively large number of toughness specimens reflects on the quality of the material with respect to slope of grain and indicates possible unsuitability of the species for some purposes.

Discussion

Because of the limited nature of the tests performed, the data cannot be given weight equal to the results of standard tests such as those reported in USDA Technical Bulletin 479.[2] Moreover, the tests of mechanical properties were conducted only on wood in the green condition, and no estimate of the effect of drying on strength properties can be made. However, experience with such limited tests over the past several years has indicated that the data obtained generally check the results of more extensive tests quite closely and can serve as a reasonable approximation of property levels for ordinary purposes.

The tests made to evaluate specific gravity of the sample material, described earlier in this report, yielded a slightly higher average value for California white oak than was obtained from the specimens used in mechanical tests. It is possible, therefore, that the strength values are a little lower than might be obtained in more extensive tests.

Based on these limited tests, the clear wood of green California white oak from Lake County appears to have better strength properties than California black oak but is inferior to canyon live oak. It would more nearly match the values presently used for the familiar white oak grown in the eastern part of the United States.

Oregon white oak from Lake County, California, is slightly inferior to that examined from Douglas County, Oregon, in average density and in most strength properties.

Conclusions

Based on the examination of a few short sections from variable tree heights and a limited number of tests, it would appear that the clear wood of both California white oak and Oregon white oak would have strength properties closely approaching those of white oak (*Q. alba*).

If the sample material included in this investigation can be considered representative of commercially available material, the numerous knots and the presence of tension wood could be expected to have a strong influence on the production of high-grade lumber. In addition to its influence on strength properties, the common occurrence of tension wood would be likely to cause excessive shrinking and warping in seasoning.

Table 1.--Characteristics of California white oak (*Quercus lobata*) and Oregon white oak (*Q. garryana*) specimens

Species	Tree No.	Total height	Merchantable length	Height of samples in trees	Average diameter of cross section	Approximate age of section	Average specific gravity	Average rings per inch	Average shrinkage in volume
		Feet	Feet	Feet	Inches	Years			Percent
California white oak	1	75	30	13	13.5	73	0.595	11.7	17.1
				27	12.2	65	.628	12.3	17.5
	2	90	30	13	13.7	87	.560	15.2	14.3
				28	13.7	77	.553	14.3	14.1
	3	...	...	7	21.8	87	.626	8.3	15.8
				15	17.5	76	.611	9.5	16.4
	4	78	30	12	13.2	70	.576	11.1	15.5
				25	11.7	65	.556	12.3	14.2
Average							.588	11.8	15.6
Oregon white oak	5	54	24	6	15.1	240	.640	34.9	16.9
				21	12.4	190	.625	34.0	17.9
Average							.632	34.4	17.4

Table 2.--Average specific gravity and shrinkage from the green to a moisture-free condition for California white oak and Oregon white oak

	Number of trees	Height in trees	Number of tests	Range	Average
		Ft.			
CALIFORNIA WHITE OAK					
Specific gravity[1]	4	7-28	53	0.447-0.765	0.588
Shrinkage					
Volumetric....percent[2]	4	7-28	53	9.3-21.5	15.6
Tangential....percent[2]	4	7-28	51	7.08-17.70	10.10
Radial........percent[2]	4	7-28	19	3.36-5.67	4.43
Longitudinal..percent[2]	4	7-28	71	0.035-0.714	0.219
OREGON WHITE OAK					
Specific gravity	1	6-21	13	0.513-0.729	0.632
Shrinkage					
Volumetric....percent[2]	1	6-21	13	13.7-21.1	17.4
Tangential....percent[2]	1	6-21	8	9.12-13.12	11.16
Radial........percent[2]	1	6-21	5	4.12-5.51	4.48
Longitudinal..percent[2]	1	6-21	21	0.087-0.508	0.283

[1] Based on volume when green and weight when moisture-free.

[2] Expressed in percent of dimension when green.

Table 3.--Results of current static bending tests of green California white oak and Oregon white oak compared with other test data

Species	Trees	Moisture content	Specific gravity[1]	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to: Proportional limit	Work to: Maximum load
	Number	Percent		P.s.i.	P.s.i.	1,000 p.s.i.	In.-lb./cu. in.	In.-lb./cu. in.
California white oak[2] (*Quercus lobata*)	4	91	0.58	4,800	8,500	1,130	1.18	11.4
Oregon white oak[3] (*Q. garryana*)	1	67	.63	3,900	7,600	820	1.07	21.2
Oregon white oak[4] (*Q. garryana*)	10	72	.64	4,600	7,700	790	1.51	13.7
California black oak[4] (*Q. kelloggii*)	10	106	.51	3,400	6,200	740	1.03	8.8
Canyon live oak[4] (*Q. chrysolepsis*)	3	62	.70	6,300	10,600	1,340	1.70	14.4
White oak[4] (*Q. alba*)	20	68	.60	4,700	8,300	1,250	1.08	11.6

[1] Based on volume when green and weight when ovendry.

[2] Average values from 7- to 13-foot height in trees represented in current tests.

[3] Average values from 6-foot height in trees represented in current tests.

[4] Average values from U.S.D.A. Tech. Bull. 479 "Strength and Related Properties of Woods Grown in the United States.

Table 4.--Results of current hardness and toughness tests of California white oak and Oregon white oak compared with other test data

Species	Trees	Hardness tests[1]				Toughness[2]			
		Moisture content	Specific gravity[3]	End hardness	Side hardness	Moisture content	Specific gravity[3]	Radial toughness	Tangential toughness
	Number	Percent		Lb.	Lb.	Percent		In.-lb.	In.-lb.
California white oak[4] (Quercus lobata)	4	90	0.56	1,060	970	87	0.56	280.3	274.1
Oregon white oak[5] (Q. garryana)	1	68	.61	1,230	1,130	66	.65	380.0	351.6
Oregon white oak[6] (Q. garryana)	10	72	.64	1,430	1,390	....	....	....	....
California black oak[6] (Q. kelloggii)	10	106	.51	910	850	....	....	....	....
Canyon live oak[6] (Q. chrysolepsis)	3	62	.70	1,590	1,570	....	....	....	....
White oak[6] (Q. alba)	20	68	.60	1,120	1,060	....	....	....	....
Red oak[7] (Q. rubra)	....	....	....	....	....	77	.53	281.0	307
Yellow birch[7] (Betula alleghaniensis)	....	....	....	....	....	77	.55	422.5	411.3

[1]Load required to embed a 0.444-inch ball to a depth of one-half its diameter.

[2]Total toughness of specimens 0.79- by 0.79- by 11 inches.

[3]Based on volume when green and weight when ovendry.

[4]Average values from 7- to 13-foot height in trees represented in current tests.

[5]Average values from 6-foot height in trees represented in current tests.

[6]Average values from U.S.D.A. Tech. Bull. 479 "Strength and Related Properties of Woods Grown in the United States."

[7]Average values from special tests, Report No. 2109, "Results of Impact Tests to Compare the Pendulum Impact and Toughness Test Methods."

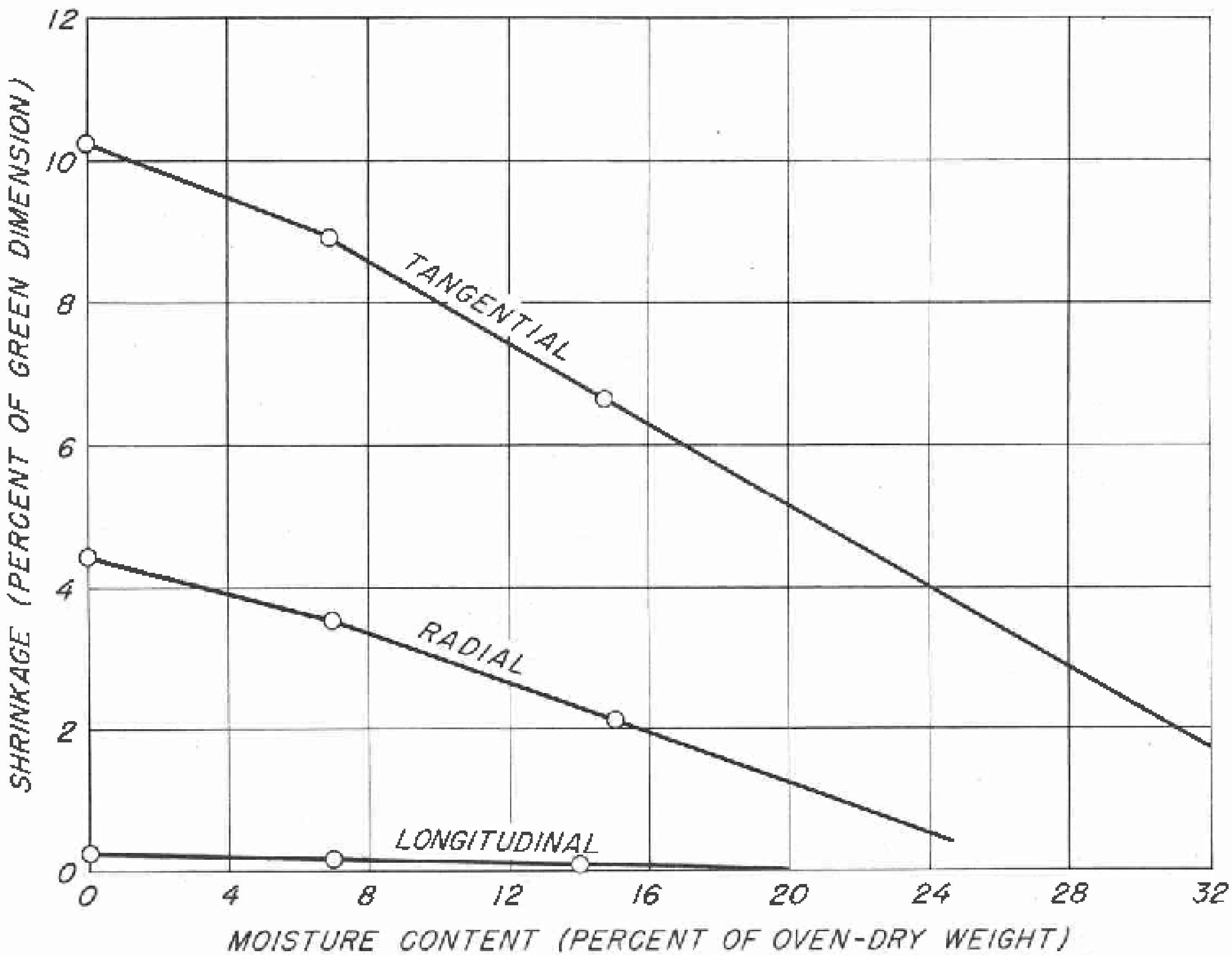

Figure 1.--Average radial, tangential, and longitudinal shrinkage of California white oak from the green to the ovendry condition. Shrinkage is expressed as a percentage of the dimension when green.

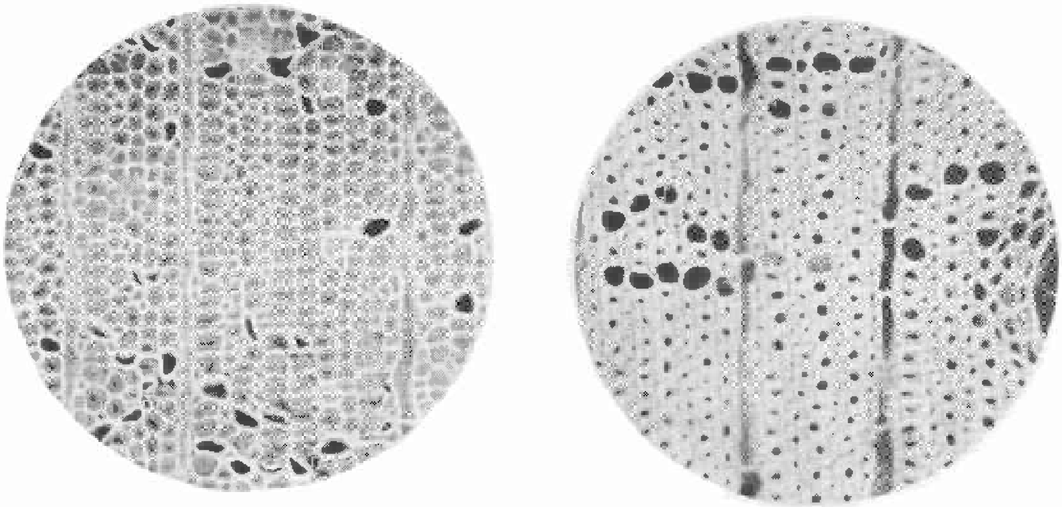

Figure 2.--Cross sections from two longitudinal shrinkage specimens of California white oak showing highly magnified cellular structure. Left -- specimen of high longitudinal shrinkage showing gelatinous fibers. Right -- specimen with very low longitudinal shrinkage having normal structure.

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