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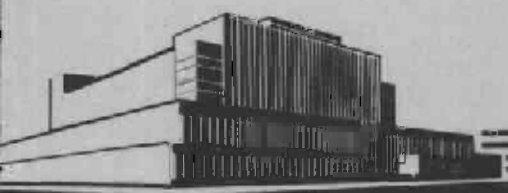

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

MECHANICAL PROPERTIES OF PONDEROSA PINE FROM THE BLACK HILLS

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Summary

This report presents the results of standard tests of strength and related properties for ponderosa pine (Pinus ponderosa) grown in the Black Hills of South Dakota. Average specific gravity and most strength properties were found to be higher for the ponderosa pine of the Black Hills than the average values published for the species, which are based on earlier tests of wood from other growth areas. Hence, published values of basic stresses for clear wood and working stresses for various grades of structural material can be considered applicable to ponderosa pine grown in the Black Hills.

Introduction

How strong is ponderosa pine from the Black Hills? Are the mechanical properties of Black Hills ponderosa pine typical of the published values for the species -- even though these values were obtained from wood grown in other areas?

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These questions arise largely because of the wide distribution of ponderosa pine in the western United States. Strength and related properties of the species were established before 1918 from evaluations of ponderosa pine from the Cascades, Sierra Nevadas, and both Northern and Southern Rocky Mountains -- but not the Black Hills. Since this area represents the eastern-most part of the tree's natural growth range and has become commercially important, the mechanical properties of Black Hills ponderosa pine were investigated to compare them with the species standards.

Material

The logs (Shipment 1701) used in this investigation were from trees cut in Pennington County, S. D., under the direction of the Rapid City Research Center of the Rocky Mountain Forest and Range Experiment Station. Complete accounts were recorded on standard forms to describe the selection areas and site characteristics, together with detailed data relating to each sample tree.

The topography was mountainous; soil was generally dry with good natural drainage; and streams had only intermittent flow. Absolute elevation of the collection area was about 4,600 feet. The selected trees were in stands composed almost entirely of ponderosa pine.

No data for average annual rainfall were available for the sample area, but at Rochford, 10 air miles west-northwest of the area, rainfall averages about 21 inches annually. Some logging was done in 1921 and 1929, and the area also shows evidence of some fire damage. Figures 1 and 2 show typical stands of ponderosa pine in the area.

Tests were made on material cut 8 to 16 feet above the stump (c-d bolts)[3] from eight representative trees, and bolts from three additional heights in tree No. 8 were also tested. Figure 3 shows the cross-section of tree No. 3 at the 12-foot height. Figure 4 shows end views of test sticks selected to represent average, slow and fast growth. Tree No. 5 was decayed near the pith, necessitating the elimination of tests from that area.

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[3] Each 4-foot section of a tree is designated as a "bolt." These are assigned letters a, b, c, etc., commencing at the butt of the tree and proceeding upward.

The average growth rate of the trees included in this shipment was slower than in five of the six shipments previously tested from other regions, and in some Black Hills trees the growth was exceptionally slow. There was a high percentage of sapwood in the South Dakota logs. Trees were from 10 to 20 inches in diameter at breast height, with merchantable lengths ranging from 40 to 58 feet. Estimated age of the trees ranged from 105 to 203 years.

Test Procedure

This shipment of ponderosa pine was collected, prepared, and tested in accordance with the American Society for Testing Materials' Designation D 143-52, "Standard Methods of Testing Small Clear Specimens of Timber."

The 8-foot double length bolts permitted the usual formation of composite bolts for tests of well-matched material in the green and dried conditions. Sticks to be used for dry specimens were kiln dried under a mild drying schedule to about 12 percent moisture content. Specimens cut from these sticks were conditioned to essentially constant weight at 75° F. and 64 percent humidity before being tested.

Some restrictions were encountered in the selection of test specimens because of the relatively small size of the trees and the presence of knots. Less than the usual four pairs of radial and tangential shrinkage pieces could be obtained. In accordance with standard practices many of the minor tests were made on pieces taken from the ends of uninjured bending specimens. Tests of cleavage and tension perpendicular to the grain were somewhat limited, especially in the dried material. No tests were made of tension parallel to the grain.

Data

Average values are listed in tables 1 and 2 for the principal mechanical properties of individual trees in the Black Hills shipment. Tables 3 and 4 show average values,[4] in both the green condition and at 12 percent moisture content, for shipments of ponderosa pine previously tested, together

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[4] Markwardt, L. J., and Wilson, T. R. C. Strength and Related Properties of Woods Grown in the United States. U. S. Dept. Agr. Technical Bulletin 479. 1935.

with revised averages for the species after the addition of the Black Hills shipment.

Tables 5 and 6 show the results of tests of wood toughness and nail withdrawal resistance in ponderosa pine from the Black Hills. The toughness tests were made on pieces of wood 0.79 by 0.79 inch in cross-section and 11 inches long. These are the first toughness values available for the species. Nail-pull tests were made on 2- by 2- by 6-inch specimens, using plain nails. Most earlier tests of nail-withdrawal resistance were made with cement-coated nails. Data from one earlier shipment, where both plain and cement-coated nails were used, are included in table 6.

Discussion

Although all eight trees tested were from a relatively small area in one section of the Black Hills, there is every reason to believe the shipment can be considered typical of ponderosa pine from that portion of its growth range. Experience has shown that, when typical trees are selected from a representative area, the variability within such a shipment is generally quite large, and approaches the variability of a much larger number of trees taken from widely separated areas within the natural growth range of a species.

Ponderosa pine grows in areas that are widely separated geographically. Under such conditions one might expect trees to differ quite markedly when grown in such scattered areas as the Sierras and Cascade Mountains of the Coastal States, the Northern and Southern Rocky Mountains, and the Black Hills. It is of particular interest, therefore, that Black Hills ponderosa pine, as represented by these tests, differs little from the average of six previous shipments from various areas. The difference is so slight that the revised average values for the species, both green and dry materials, are changed only slightly by addition of this shipment, and then generally upward.

This Black Hills sample grew at a somewhat slower rate than the average of the six previous shipments. The growth rate was about the same for the Black Hills as for material collected in Arizona, and only the growth in the Colorado sample was slower.

Radial and tangential shrinkage averaged about as low for the Black Hills specimens as for any of the four earlier shipments for which such data are available; therefore, these values were lower than the average previously published for the species. Volumetric shrinkage average a little higher than the previous averaged for the species, but the difference is of no consequence.

The average specific gravity of the Black Hills sample, based on weight when ovendry and volume when green or at 12 percent moisture content, was higher than four of the earlier shipments, representing Arizona, Montana, and two places in California; was about equal to the Colorado sample; and was lower than the one from Washington. Inasmuch as property values are generally fairly well related to specific gravity, it could be expected that Black Hills ponderosa pine would also compare favorably in strength with material from other areas. The data bear out that supposition.

Tables 1 through 4 show that, in most properties, average values for Black Hills ponderosa pine tended to be higher than those for all previous shipments except the denser sample from Washington, for which data are not available in many properties. The major exceptions to that trend are proportional limit values in compression parallel and perpendicular to the grain. In those cases, the apparently lower average values do not reflect a real reduction in property values but rather a difference due to modifications in testing techniques.

All of the previous shipments of ponderosa pine were tested before 1918. Since then, test methods have been developed that permit more accurate measurement of stress-strain data in static tests. In all species these developments have tended to reduce the apparent values for proportional limit and such associated properties as work to proportional limit.

When this factor is taken into account, it is evident that the properties of Black Hills ponderosa pine compare favorably with those of ponderosa pine grown elsewhere. In static bending tests in the green condition, for example, modulus of rupture is about 10 percent higher for the Black Hills specimens than the average of the previous shipments; modulus of elasticity is about 14 percent higher; work to maximum load is 8 percent higher; and total work is about 60 percent higher. A comparison of values from tests of dry material also shows substantial increases for the Black Hills wood in those properties.

Values for maximum crushing strength, impact bending, hardness, and tension perpendicular to grain are also higher than the previous species averages, both in the green and dry conditions. Shear values in the green condition are about 13 percent higher than the previous average, but about 12 percent lower in the dry condition. On the other hand, cleavage values showed no increase over the previous species average when green, but showed about a 9 percent increase when dry. Such variations among properties are not uncommon and, as a whole, substantiate a generally higher level of property values in the Black Hills material.

Values of fiber stress at proportional limit in compression perpendicular to grain are substantially lower than the previous average for the species for both the green and dry wood. As indicated earlier, there is little doubt that differences in test methods account for these large variations. For example, a recent reevaluation of Douglas-fir properties[5] disclosed that shipments tested under modern methods averaged about 30 percent lower than those tested in earlier years. The current ponderosa pine tests show about the same reduction in relation to the previous species average.

The relatively high values obtained for impact bending from this shipment indicate that its shock resistance is high as compared with that of other shipments of ponderosa pine. Further evidence of shock resistance is afforded by the toughness data (table 5). In common with most softwood species, the tangential toughness (obtained when a specimen is loaded on a tangential face) is higher than the radial toughness (when the load is applied on a radial face). No direct comparison with ponderosa pine from the other areas can be made.

Direct comparisons with other species are also 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. Tests of shortleaf pine from Alabama and Virginia and loblolly pine from Arkansas yielded toughness values in the neighborhood of 310 to 320 inch-pounds for radial specimens and 440 to 455 inch-pounds for tangential specimens. The average specific gravity of the wood tested varied from about 0.46 to 0.49. While the difference in toughness of ponderosa pine and these southern pines seems quite large, it is known that specific gravity strongly affects toughness, and the averages obtained for Black Hills ponderosa pine are actually somewhat higher than might be anticipated for material having a specific gravity so much lower than that of the southern pine.

Average values for the resistance to nail withdrawal for the Black Hills shipment, as presented in table 6, are for withdrawal of sevenpenny plain sinker nails. Comparative values for that type of nail and for sevenpenny cement-coated nails are also listed for ponderosa pine in the shipment from California. Extensive tests of other species have indicated that differences in moisture content at the 7 to 12 percent moisture level have little effect on resistance to immediate withdrawal of plain nails; however, cement-coated nails are much higher in immediate withdrawal resistance than plain nails, as may be seen from the comparative data for the California shipment where both types of

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[5] Drow, John T. Relationship of Locality and Rate of Growth to Density and Strength of Douglas-fir. Forest Products Laboratory Rept. No. 2078. 1957.

nails were tested on the same specimens. Other types of nails and other test conditions will, of course, affect nail-withdrawal loads. The data from current tests are not readily comparable with those for other species, but the results will be useful in making comparisons in future tests conducted under current standard practices.

Average values from three sections of the tree trunk in addition to the standard 8- to 16-foot height (c-d bolts) are listed in tables 1 and 2 for tree No. 8. These represent the 0- to 8-foot height (a-b bolts), the 24- to 32-foot height (g-h bolts), and the 40- to 48-foot height (k-l bolts). The data in tables 1 and 2 show that the 8-foot length next to the stump had a substantially higher specific gravity than the c-d bolts, and tended to have somewhat higher property values. Conversely, the g-h and k-l bolts had lower specific gravity and generally lower property values than the c-d standard. These relations are in agreement with other shipments and species; specific gravity and property levels generally decline with increased height in the tree. However, published data on averages for the species represent only the c-d bolt or nearest equivalent; hence, standard comparisons among or within species must be made for c-d bolts only, and the additional data from other parts of a typical tree serve only as supplementary information.

The Forest Products Laboratory has the responsibility for recommending suitable basic stresses for the clear wood of important structural species, including ponderosa pine. Such basic stresses are derived primarily from average species properties in the green condition, together with suitable allowances for variability, duration of load, loading conditions, a factor of safety, and engineering judgment.

Actual working stresses for various structural grades of any species are derived from basic stresses that represent clear wood; a suitable grade ratio is applied to reflect the extent to which strength-reducing characteristics, such as knots, shake, checks, slope of grain, and the like, are permitted in specified grades.

Conclusions

The data included in this report clearly show that the strength properties of ponderosa pine from the Black Hills approach the best values previously obtained from clear wood of the species, and are generally higher than published average values that are intended to represent the species. In view of these findings, the basic stresses published for ponderosa pine as a whole

can also be considered fully applicable to ponderosa pine grown in the Black Hills. Working stresses for specified grades of ponderosa pine lumber can also be considered applicable to Black Hills material that meets such grade requirements, as grade ratios are independent of species or locality.

Table 1.--Strength and related properties of green and kiln dried ponderosa pine from Pennington County, S. D.

Tree No.	Bolt No.	Rings per inch	Moisture content	Specific gravity, based on ovendry volume		Shrinkage from green to ovendry condition, based on dimensions when green			Static bending						Impact bending			
									Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to proportional limit	Work to maximum load	Work total	Stress at proportional limit	Work to proportional limit	Modulus of elasticity	Height of drop causing complete failure (50-lb. hammer)
				At test	When ovendry	Volumetric	Radial	Tangential										
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
		Number	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.	In.-lb. per cu. in.	P.s.i.	In.-lb. per cu. in.	1,000 p.s.i.	In.
GREEN																		
1	c-d	20.7	156.2	0.380	0.440	9.9	3.83	5.90	3,540	6,000	1,190	0.59	5.80	22.40	7,340	2.4	1,260	19.0
2	c-d	27.2	134.8	.384	.455	10.3	3.61	6.15	2,960	5,470	989	.50	5.76	16.47	7,670	2.2	1,490	28.0
3	c-d	27.9	93.0	.414	.464	9.7	4.26	6.57	3,300	5,920	1,227	.50	5.89	21.80	8,500	2.8	1,441	28.5
4	c-d	14.9	134.2	.382	.415	8.9	3.51	6.05	2,930	5,630	1,066	.46	6.69	14.70	7,480	2.6	1,198	23.0
5	c-d	28.2	103.0	.369	.424	9.6	3.58	5.60	2,860	5,120	1,091	.42	4.24	19.84	7,800	2.6	1,307	20.7
6	c-d	20.7	123.0	.386	.439	10.1	3.31	5.72	3,290	5,910	1,128	.56	5.59	29.57	8,110	2.8	1,346	27.7
7	c-d	18.3	137.7	.396	.440	10.2	3.29	5.37	2,980	5,290	1,002	.51	5.15	16.07	7,660	2.6	1,252	23.0
8	c-d	21.6	136.9	.375	.420	10.1	3.69	5.97	3,050	5,320	1,162	.45	4.71	19.74	7,830	2.7	1,279	23.7
Average		22.4	127.4	.386	.437	9.8	3.64	5.92	3,110	5,580	1,107	.50	5.48	20.07	7,800	2.6	1,322	24.2
8	a-b	20.6	121.4	.405	.445	10.0	4.06	6.20	3,180	5,340	1,129	.50	5.13	23.65	7,420	2.7	1,145	31.5
8	g-h	18.4	147.7	.361	.404	9.3	3.55	5.63	2,580	5,180	1,048	.36	5.46	17.02	7,300	2.6	1,145	20.5
8	k-l	15.8	166.7	.354	.393	8.9	3.60	5.52	2,780	4,930	921	.47	4.93	13.35	7,560	2.6	1,206	19.0
KILN DRIED																		
1	c-d	19.0	11.6	.417					6,360	11,010	1,472	1.57	9.27	12.27	7,590	1.9	1,705	20.0
2	c-d	25.0	11.7	.409					5,260	10,230	1,359	1.14	8.78	10.42	10,520	3.9	1,720	20.0
3	c-d	24.4	11.7	.441					6,380	11,400	1,599	1.44	9.98	16.26	12,780	4.8	1,874	32.0
4	c-d	15.2	11.5	.394					5,460	9,510	1,301	1.33	8.26	8.26	12,040	5.2	1,604	21.5
5	c-d	27.1	11.4	.408					6,100	10,340	1,450	1.44	8.06	10.36	13,180	5.6	1,740	20.7
6	c-d	20.8	11.5	.411					5,940	10,320	1,413	1.43	8.36	14.13	11,840	5.0	1,574	29.2
7	c-d	18.1	11.4	.418					5,650	10,130	1,349	1.34	8.58	9.66	11,560	5.0	1,506	19.0
8	c-d	22.7	11.5	.403					5,410	9,940	1,444	1.14	9.25	11.27	11,660	4.6	1,695	24.9
Average		21.5	11.5	.413					5,820	10,360	1,423	1.35	8.82	11.58	11,400	4.5	1,677	23.4
Average adjusted			12.0	.412					5,700	10,160	1,412	1.31	8.69	11.79	11,190	4.4	1,658	23.4
8	a-b	20.5	11.4	.422					6,410	10,550	1,386	1.65	10.41	14.91	12,710	5.5	1,672	26.8
8	g-h	18.8	11.0	.389					5,720	9,770	1,237	1.52	8.40	10.70	10,000	3.9	1,414	20.0
8	k-l	15.2	11.1	.378					4,970	9,280	1,232	1.12	10.10	12.50				

Table 2.--Strength and related properties of green and kiln dried ponderosa pine from Pennington County, S. D.

Tree No.	Bolt No.	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; load required to embed a 0.444-inch ball to 1/2 its diameter: Side	Shear parallel to grain; maximum shearing strength	Cleavage; load to cause splitting	Tension perpendicular to grain; maximum tensile strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		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.
					GREEN					
1	c-d	1,710	1,404	2,600	274	364	356	727	164	.....
2	c-d	1,580	1,293	2,620	221	317	329	808	189	362
3	c-d	1,760	1,560	2,930	272	362	357	818	186	360
4	c-d	1,460	1,148	2,440	231	362	353	724	166	351
5	c-d	1,450	1,343	2,460	236	340	343	734	164	340
6	c-d	1,690	1,369	2,830	257	347	359	816	165	352
7	c-d	1,570	1,299	2,640	312	350	346	782	176	358
8	c-d	1,560	1,345	2,580	246	313	330	753	166	352
Average		1,600	1,345	2,640	256	344	347	770	172	353
8	a-b	1,580	1,219	2,520	249	337	322	732	176	385
8	g-h	1,480	1,288	2,310	207	316	306	698	163	327
8	k-l	1,630	1,166	2,260	228	298	302	660	149	318
					KILN DRIED					
1	c-d	3,890	1,649	5,900	491	665	560	975	.....	389
2	c-d	3,570	1,533	5,600	523	619	490	1,044	.....	370
3	c-d	4,060	1,766	6,200	531	717	582	1,039	259	550
4	c-d	3,380	1,393	5,180	495	586	460	1,032	258	462
5	c-d	4,130	1,577	5,410	566	644	446	1,130	203	468
6	c-d	4,020	1,558	5,840	426	586	493	971	.....	.....
7	c-d	3,620	1,405	5,480	448	577	490	1,094	239	454
8	c-d	3,970	1,566	5,580	454	644	475	992	244	481
Average		3,830	1,556	5,650	492	630	500	1,034	248	477
Average adjusted		3,700	1,547	5,480	484	618	494	1,017	244	471
8	a-b	3,350	1,430	5,370	458	639	560	1,158	248	416
8	g-h	3,450	1,554	5,380	406	596	428	852	242	397
8	k-l	3,070	1,475	5,340	380	533	418	917	.....	352

Table 3.--Comparison of strength and related properties of ponderosa pine from various areas and revised averages for the species (all c-d bolts)

Locality of growth	Number of trees	Rings per inch	Moisture content	Specific gravity, based on volume		Shrinkage from green to ovendry condition based on dimensions when green			Static bending						Impact bending			
				At test	When ovendry	Volumetric	Radial	Tangential	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to proportional limit	Work Maximum load	Work Total	Stress at proportional limit	Work to proportional limit	Modulus of elasticity	Height of drop causing complete failure (50-lb. hammer)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
		Number	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.	In.-lb. per cu. in.	P.s.i.	In.-lb. per cu. in.	1,000 p.s.i.	In.
Pennington Co., S. D.	8	22.4	127.4	0.386	0.437	9.8	3.64	5.92	3,110	5,580	1,107	0.50	5.48	20.07	7,800	2.6	1,322	24.2
			1/12.0	.412					5,700	10,160	1,412	1.31	8.69	11.79	11,190	4.4	1,658	23.4
Douglas Co., Colo.	5	31.9	92.7	.391	.435	9.9	3.8	5.8	3,310	5,460	1,053	.59	6.00	11.49	6,910	2.2	1,203	20.0
			1/12.0	.415					6,680	9,980	1,288	2.00	7.12	8.21	8,110	2.8	1,347	17.9
Stevens Co., Wash.		15.9	1/37.6	.415					3,390	5,660	1,160							
			1/12.0	.434					6,520	10,640	1,521							
Coconino Co., Ariz.	5	21.4	98.5	.353	.395	9.2	4.1	6.4	2,660	4,760	879	.47	4.90	12.84	6,160	2.1	979	17.0
			1/12.0	.383					6,540	8,300	1,112	2.15	4.59	7.18	8,220	3.2	1,285	9.7
Madera Co., Calif.	5	13.0	125.3	.377	.433	11.5	4.3	7.3	3,180	5,180	1,111	.52	4.30	15.55	7,070	2.5	1,115	21.0
			1/12.0	.397					7,010	9,800	1,395	1.98	7.39	18.39	10,260	4.2	1,412	19.3
Missoula Co., Mont.	5	17.9	119.4	.371	.425	9.3	3.5	5.9	2,930	4,950	865	.59	5.20	15.42	6,500	2.3	1,061	19.0
			1/12.0	.393					5,690	8,150	1,208	1.55	5.80	12.55	10,940	4.8	1,479	19.0
Sierra Co., Calif.	6	12.6	1/75.4	.370	.412	8.4			3,140	4,260	779	.74	5.10	7.77	7,080	3.4	822	21.1
			1/12.0	.393					5,560	8,700	1,083	1.61	7.89	8.10	11,050	4.8	1,428	19.0
Adjusted species average (weighted) 2/		19.4	1/98.4	.381	.424	9.7	3.8	6.2	3,100	5,130	997	.57	5.19	14.23	7,000	2.6	1,097	20.7
			1/12.0	.404					6,180	9,430	1,293	1.72	7.10	11.02	10,100	4.1	1,454	18.6

1/ Adjusted to 12 percent moisture content.

2/ Weighted species averages include limited tests of shipment from Stevens County, Wash.

Table 4.--Comparison of strength and related properties of ponderosa pine from various areas and revised averages for the species (all c-d bolts)

Locality of growth	Moisture content	Compression parallel to grain			Compression perpendicular to grain; stress at proportional limit	Hardness; load required to embed a 0.444-inch ball to 1/2 its diameter		Shear parallel to grain; maximum shearing strength	Cleavage; load to cause splitting	Tension perpendicular to grain; maximum tensile strength
		Stress at proportional limit	Modulus of elasticity	Maximum crushing strength		End	Side			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Percent	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.
Pennington Co., S. D.	127.4	1,600	1,345	2,640	256	344	347	770	172	353
	±12.0	3,700	1,547	5,480	484	618	494	1,017	244	471
Douglas Co., Colo.	92.7	2,240	1,174	2,600	410	315	331	706	153	.....
	±12.0	4,700	1,258	5,510	778	675	474	1,078	210	.....
Stevens Co., Wash.	37.6	.....	.....	2,770	299	.....	.....	.....	.....	.....
	±12.0	.....	.....	6,130	757	.....	.....	.....	.....	.....
Coconino Co., Ariz.	98.5	1,870	1,046	2,220	342	310	314	662	166	301
	±12.0	3,740	1,219	5,080	790	539	406	1,315	244	401
Madera Co., Calif.	125.3	2,130	1,271	2,420	326	316	314	696	174	241
	±12.0	4,400	1,489	5,620	682	508	468	1,103	216	398
Missoula Co., Mont.	119.4	2,050	1,061	2,370	313	308	322	674	176	302
	±12.0	3,650	1,557	5,140	618	484	437	955	190	358
Sierra Co., Calif.	75.4	.....	.....	2,060	428	258	286	682	168	310
	±12.0	.....	.....	4,350	800	564	450	1,340	224	451
Adjusted species average (weighted)[2]	98.4	1,940	1,197	2,450	335	310	321	704	168	306
	±12.0	4,000	1,428	5,320	687	569	458	1,130	224	423

[1] Adjusted to 12 percent moisture content.

[2] Weighted species averages include limited tests of shipment from Stevens County, Wash.

Table 5.--The results of toughness tests on ponderosa pine from Pennington County, S. D. Specimens 0.79- by 0.79- by 11-inches. Tested on a 9.47-inch span.

Tree No.	Bolt No.	Loaded on radial face				Loaded on tangential face			
		Number of tests	Moisture content	Specific gravity[1]	Toughness[2]	Number of tests	Moisture content	Specific gravity[1]	Toughness[2]
			Percent		In.-lb.		Percent		In.-lb.
GREEN									
1	c-d					1	148.1	0.397	294.9
2	c-d								
3	c-d	2	116.7	0.402	234.4	2	118.6	.414	301.1
4	c-d	5	155.6	.376	179.1	5	146.3	.384	253.4
5	c-d	12	132.4	.366	144.9	11	141.9	.366	196.3
6	c-d	9	145.6	.375	232.9	9	146.4	.376	286.3
7	c-d	1	169.3	.368	167.6	2	158.6	.375	267.8
8	c-d	10	139.0	.378	187.7	9	146.2	.374	257.0
Average		39	143.1	.378	191.1	39	143.7	.384	265.3
8	a-b	9	147.2	.383	249.0	9	151.6	.384	292.1
8	g-h	3	144.9	.379	166.3	3	147.3	.365	240.6
8	k-l								
KILN DRIED									
1	c-d	3	10.8	0.425	143.9	2	10.8	0.442	201.4
2	c-d	3	10.5	.418	112.9	3	11.0	.436	152.7
3	c-d	5	10.6	.448	174.8	3	10.4	.454	251.6
4	c-d	5	11.0	.414	142.1	7	10.9	.406	156.7
5	c-d	10	11.1	.419	138.1	10	11.0	.419	178.5
6	c-d	8	11.2	.423	158.8	5	11.5	.428	222.1
7	c-d	7	10.9	.435	140.0	7	11.3	.433	177.4
8	c-d	10	11.2	.411	160.1	10	11.2	.412	218.0
Average		51	10.9	.424	146.3	47	11.0	.429	194.8
8	a-b	8	11.1	.434	190.1	6	11.3	.432	246.6
8	g-h	2	11.0	.394	128.0	3	10.6	.404	172.7
8	k-l	1	11.3	.382	140.8	1	10.4	.392	199.8

[1] Specific gravity based on volume at test and weight when ovendry.

[2] Total toughness -- inch-pounds per specimen.

Table 6.--The results of nail-withdrawal tests on ponderosa pine

Tree No.	Bolt No.	Green					Kiln dried				
		Number of pieces	Moisture content	Specific gravity[1]	Nail-withdrawal load[2]			Number of pieces	Moisture content	Specific gravity[1]	Nail-withdrawal load[2]		
					End	Radial	Tangential				End	Radial	Tangential
			Percent		Lb.	Lb.	Lb.		Percent		Lb.	Lb.	Lb.
PENNINGTON COUNTY, S. D. (BLACK HILLS)													
1	c-d	0						2	11.7	0.417	78	115	124
2	c-d	4	141.1	0.365	63	121	136	4	11.8	.445	87	120	128
3	c-d	5	114.7	.397	71	146	143	5	12.2	.448	86	135	124
4	c-d	2	101.8	.364	73	102	116	5	11.8	.407	66	92	103
5	c-d	5	109.9	.373	62	120	124	7	11.6	.414	77	112	108
6	c-d	4	101.3	.410	54	116	122	6	11.5	.417	70	108	106
7	c-d	5	126.5	.400	62	134	130	5	11.4	.431	72	99	107
8	c-d	6	142.5	.366	67	126	135	6	11.0	.416	71	104	103
Average		31	119.7	.382	65	124	129	40	11.6	.424	76	111	113
8	a-b	5	127.4	.388	51	119	122	3	11.3	.429	72	114	114
8	g-h	4	135.0	.363	43	104	102	3	11.1	.393	65	98	101
8	k-l	3	139.9	.350	56	110	98	2	11.2	.378	62	98	98
MADERA COUNTY, CALIF.[3]													
								7.2		.41	2-54[4]	2-83[4]	2-84[4]
								7.2		.41	107[4]	203[4]	218[4]

[1] Specific gravity based on volume at test and weight when ovendry.

[2] Load in pounds required to remove sevenpenny sinker nails immediately after being driven to a 1-1/4-inch penetration. (End, radial, and tangential refer to faces from which nail is withdrawn.)

[3] Test material represented 5 trees.

[4] Load in pounds required to remove sevenpenny cement-coated nails immediately after being driven to a 1-1/4-inch penetration.

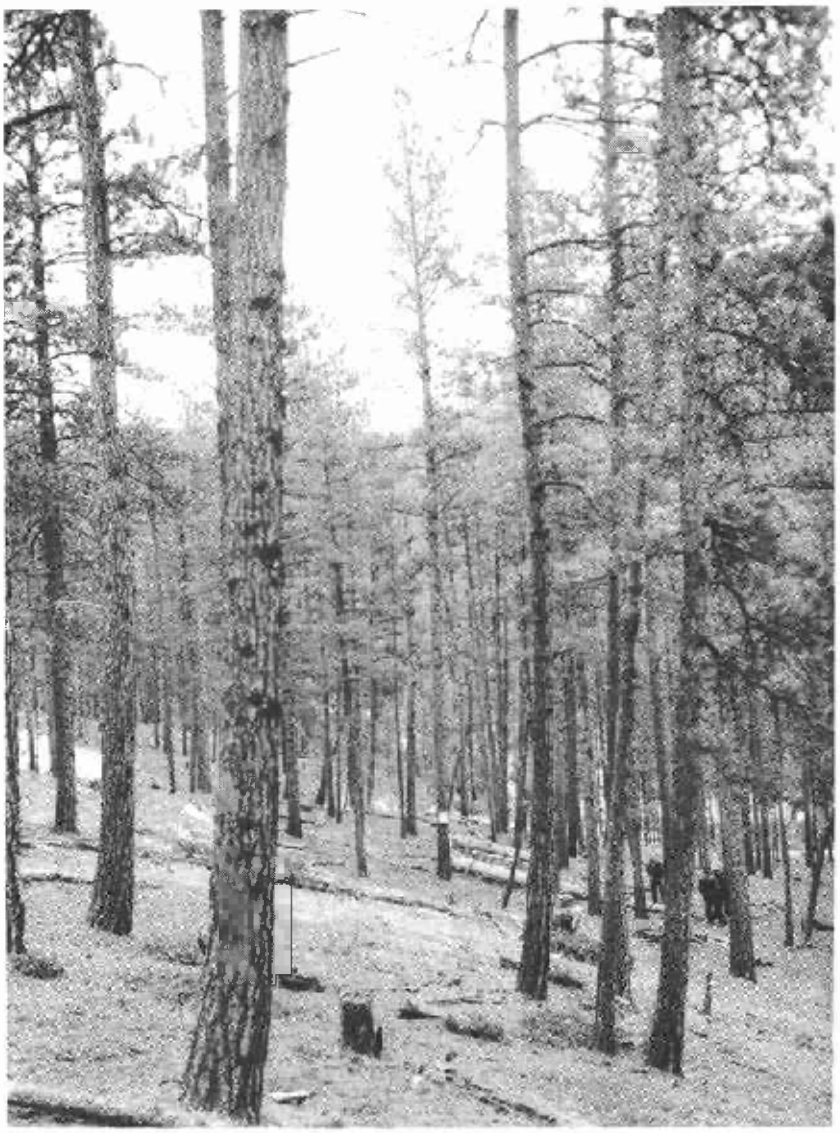

Figure 1. --Typical stand of ponderosa pine in Pennington County, S. D., showing tree No. 8 before it was cut.

Z M 108 840

Figure 2. --Ponderosa pine trees, numbered 3, 5, 6, and 8 in this investigation, came from this site in the Black Hills.

Z M 108 841

Figure 3. --Cross sectional view of a representative ponderosa pine tree from Pennington County, S. D. (tree No. 3 at the 12-foot height).

Z M 107 919

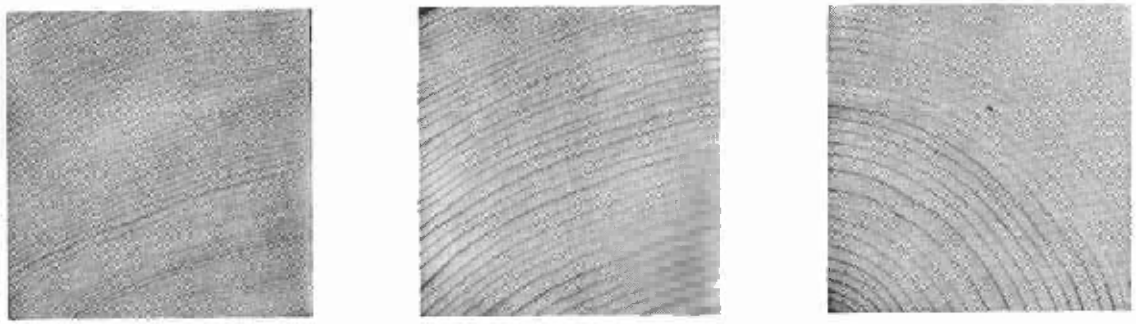

Figure 4. --Slow, medium, and fast growth is shown, left to right, in these blocks of ponderosa pine from Pennington County, S. D.

Z M 111 776