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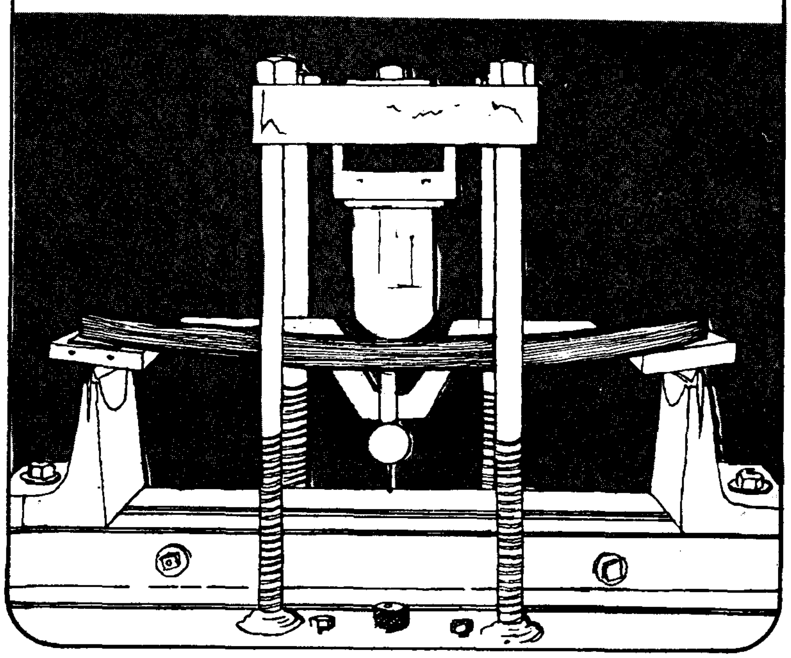
Strength and Related Properties of Mountain Hemlock



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SUMMARY

Most strength and related properties of small clear specimens of mountain hemlock (Tsuga mertensiana) from two locations in Oregon were determined to be slightly lower than the species averages based on previous comparable evaluations of material from Montana and Alaska. This is more noticeable for green wood than for wood at 12 percent moisture content. Consideration of all available data indicates that standard strength properties of mountain hemlock are generally comparable to those of western hemlock (T. heterophylla), with the possible exception of the lower average modulus of elasticity for mountain hemlock.

Strength and Related Properties of Mountain Hemlock

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INTRODUCTION

Mountain hemlock (Tsuga mertensiana (Bong.) Carr.), also known as black or alpine hemlock, is a timber tree grown at high elevations in the mountains from southern Alaska to central California and in parts of western Nevada, western Montana, and northern Idaho (2).[3] It is commonly found in mixture with other species, but forms some nearly pure stands in parts of the Cascade Mountains (2, 5). Historically it has not been an important timber species but, in recent years, improved access to the forest and removal of more readily accessible timber has led to increased use of this wood. In some regions, mountain hemlock is commonly marketed for poles and lumber in mixture with western hemlock (Tsuga heterophylla) without distinction between the two.

The first evaluation of strength and related properties of small clear specimens of mountain hemlock was made at the Forest Products Laboratory in 1913 on a shipment representing five trees from Missoula County, Mont. This was followed in 1924 by a similar shipment of material from five trees from the vicinity of Girdwood, Alaska. The results of those evaluations indicated that

[1]Based on research done by A. W. Dohr, formerly of the Forest Products Laboratory staff.

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

[3]Underlined numbers in parentheses refer to Literature Cited at the end of this report.

the wood of mountain hemlock averaged somewhat denser and slightly stronger in most respects than that of western hemlock. The notable exceptions were modulus of elasticity in static bending, in which mountain hemlock averaged somewhat lower than western hemlock, and modulus of elasticity in compression parallel to grain, in which the difference was even more pronounced. Of the two shipments of mountain hemlock, that from Alaska averaged denser and stronger than that from Montana (4).

Further sampling of mountain hemlock was undertaken by the Forest Service in 1956. That provided for a reevaluation of the species properties, including material from an important producing area not previously sampled, and serves as the basis for the study described here. The material was collected by personnel of Oregon State University with assistance from the staffs of the Pacific Northwest Forest and Range Experiment Station and the Mt. Hood National Forest, according to a plan developed at the Forest Products Laboratory.

Description of Materials

Material for this further evaluation of the standard strength and related properties of mountain hemlock consisted of two shipments representing two locations in Oregon. One shipment, consisting of d bolts (12- to 16-foot height) from-six trees and bolts from several heights of one of the trees, was collected on the Mt. Hood National Forest in Hood River County, Oreg., at an elevation of 4,850 feet. Another shipment, consisting of d bolts from eight trees and bolts from several heights of one tree, was collected on the Umpqua National Forest in Windigo Pass, Douglas County, Oreg., at an elevation of 5,660 feet. Both of the source areas are mountainous and have generally similar climatic conditions.

Both shipments represented old-growth timber, but the trees sampled from Douglas County averaged somewhat smaller and included a wider range of ages than those from Hood River County. Trees represented in the shipment from Hood River County ranged from 16 to 23 inches diameter at breast height and from 220 to 260 years old at the stump with an average merchantable length of about 70 feet. Those represented in the shipment from Douglas County ranged from 11 to 20 inches diameter at breast height and from 165 to 280 years old at the stump, with an average merchantable length of about 50 feet. Cross sections of bolts from various heights in one tree of each shipment are shown in figures 1 and 2.

The bolts were sent to the Forest Products Laboratory in October 1956 and evaluations were conducted during 1957 through 1959.

Figure 1.--Cross sections of a tree from Hood River County, Oreg., at heights of 4, 12, 40, and 72 feet. Compression wood (characterized by wide, dark, summerwood bands) is apparent in b and d, and uniform, clear growth can be observed in the wood higher in the tree (bolts k and s).

Figure 2.--Cross sections of a tree from Douglas County, Oreg., at heights of 4, 12, 32, and 60 feet. Only limited areas of compression wood are noticeable (bolts b and d) and there is generally uniform growth throughout the height of the tree (bolts i and p).

Procedures

Specimen selection and test methods for material in the green and air -dry conditions were as described for the secondary method in American society for Testing and Materials Designation D 143-52, "Standard Methods of Testing Small Clear Specimens of Timber." The secondary method was used because of the small size and the frequency of knots in several of the bolts.

The shortage of clear material available and the presence of localized grain deviations and abnormal wood limited the number of acceptable specimens on which the reported data are based, Also, these factors prevented selection of specimen material for evaluation of properties in impact bending, tension perpendicular to the grain, and cleavage.

Presentation of Results

Shrinkage data are presented in table 1. Data on mechanical properties in the green condition are presented in table 2 and in the air -dry condition in table 3. Comparable data resulting from previous evaluations of mountain hemlock and western hemlock are also presented in tables 2 and 3 (4,7). Data on variation in strength and related properties of the green wood of all material of the species evaluated are presented in table 4. The presentation is confined to data for green wood because of the problem of adjusting data for air-dry wood to eliminate effects of differences in moisture content. Variability characteristics of air -dry wood have been observed to be closely comparable to those of green wood (8). Index numbers for mountain hemlock, based on average values of strength and related properties of small clear specimens, and comparative index numbers for a few other species are presented in table 5. The index numbers are comparable to those presented in Forest Products Laboratory Report No. 1169 (6) and were computed in the same -manner as those index numbers (3).

Discussion of Results

The mountain hemlock from Oregon evaluated in this research averaged lower in density and slightly lower in shrinkage than the mountain hem-

Table 1.--Shrinkage and other physical characteristics of mountain hemlock from Oregon

Tree No.	Bolt	Rings per inch	Specific gravity[1]	Shrinkage, green to-- 75° F., 64 percent humidity: Moisture content	Radial	Tangential	Volumetric	80° F., 30 percent humidity: Moisture content	Radial	Tangential	Ovendry: Radial	Tangential	Volumetric
				Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
SHIPMENT FROM HOOD RIVER COUNTY, OREG.													
1	d	31	0.37	15.0	1.7	3.3	4.2	7.2	3.0	5.3	4.0	6.8	9.7
2	d	33	.39	14.8	1.8	3.6	5.2	7.2	3.3	5.7	4.4	7.3	10.9
3	d	27	.41	14.6	1.6	3.2	4.7	7.1	3.0	5.1	4.0	6.6	10.3
4	d	36	.40	15.1	1.4	3.0	4.8	7.1	2.7	4.9	3.6	6.4	10.8
5	d	28	.38	14.4	1.5	3.2	3.9	7.0	2.7	5.0	3.7	6.4	9.2
6	d	35	.42	14.6	1.5	3.9	5.0	7.2	2.8	6.2	3.8	8.0	11.2
Average		32	.40	14.8	1.6	3.4	4.6	7.1	2.9	5.4	3.9	6.9	10.4
3	b	33	.43	15.0	1.6	2.7	4.4	7.4	2.9	4.3	3.9	5.6	10.0
3	k	28	.41	14.6	1.7	3.0	4.4	7.0	3.1	4.9	4.2	6.4	10.0
3	s	28	.45	14.9	1.7	3.1	4.4	7.2	3.2	5.1	4.3	6.7	10.3
SHIPMENT FROM DOUGLAS COUNTY, OREG.													
1	d	32	.42	15.0	1.4	3.5	5.2	7.2	3.1	5.5	4.1	7.0	11.6
2	d	23	.38	15.0	1.8	3.5	5.7	7.2	3.2	5.5	4.2	7.0	11.7
3	d	34	.45	14.8	2.4	4.0	6.2	7.1	4.0	6.2	5.3	7.7	12.1
4	d	25	.43	15.2	2.3	3.7	6.0	7.4	4.0	5.9	5.3	7.5	12.2
5	d	32	.42	14.9	2.3	3.5	5.3	7.2	4.0	5.6	5.3	7.1	10.9
6	d	16	.40	15.0	2.0	3.5	4.8	7.2	3.4	5.5	4.4	6.9	10.5
7	d	30	.41	15.1	2.1	2.7	5.0	7.2	3.6	4.7	4.8	6.2	10.8
8	d	36	.40	14.8	1.8	3.5	5.2	7.2	3.2	5.5	4.4	7.1	11.3
Average		28	.41	15.0	2.0	3.5	5.4	7.2	3.6	5.6	4.7	7.1	11.4
2	b	24	.37	15.2	2.0	3.3	5.2	7.3	3.5	5.1	4.5	6.6	11.1
2	i	21	.39	14.6	1.9	3.3	5.2	7.2	3.4	5.3	4.5	6.8	10.8
2	p	26	.41	14.8	1.8	3.4	5.2	7.3	3.3	5.5	4.6	7.1	11.2
AVERAGE OF SHIPMENTS FROM OREGON--"D" BOLTS (WEIGHTED)													
......	......	30	.40	14.9	1.8	3.4	5.1	7.2	3.3	5.5	4.4	7.0	11.0
AVERAGE BASED ON PREVIOUS DATA													
......	......	......	.43	......	......	......	......	......	......	......	4.4	7.4	11.4
NEW AVERAGE BASED ON ALL DATA													
......	......	......	.42	......	......	......	......	......	......	......	4.4	7.2	11.2

[1] Specific gravity based on green volume and ovendry weight.

Table 2.--Mechanical properties of mountain hemlock, green (shipments from Oregon)

Tree No.	Bolt	Moisture content	Specific gravity[1]	Static bending[2]: Stress at proportional limit	Static bending[2]: Modulus of rupture	Static bending[2]: Modulus of elasticity	Static bending[2]: Work: Proportional limit	Static bending[2]: Work: Maximum load	Compression parallel to the grain[2]: Stress at proportional limit	Compression parallel to the grain[2]: Modulus of elasticity	Compression parallel to the grain[2]: Maximum crushing strength	Compression perpendicular to the grain	Hardness: End	Hardness: Side	Maximum shearing strength	Toughness[3]: Radial	Toughness[3]: Tangential
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
		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.	In.-lb.	In.-lb.
SHIPMENT FROM HOOD RIVER COUNTY, OREG.																	
1	d	51	0.37	3,000	5,500	910	0.59	10.0	1,510	1,040	2,510	330	510	390	880	190	170
2	d	62	.39	3,200	5,800	950	.61	11.4	1,780	1,040	2,660	320	560	430	890	260	330
3	d	75	.41	3,000	6,000	970	.53	10.5	1,650	1,010	2,640	350	550	450	990	250	290
4	d	42	.40	3,400	6,000	1,030	.63	11.2	1,950	1,140	2,830	260	570	380	880	150	250
5	d	54	.38	2,900	5,600	930	.54	8.4	1,640	1,100	2,530	400	580	430	880	220	240
6	d	53	.42	4 100	6,800	1,200	.82	10.6	2,030	1,430	3,100	390	570	480	1,040	180	220
Average		56	.40	3,300	5,900	1,000	.62	10.4	1,760	1,130	2,710	340	560	430	930	210	250
3	b	102	.43	2,900	5,900	840	.57	13.0	1,660	910	2,670	440	600	500	1,010	260	260
3	k	66	.41	3,800	6,400	1,000	.81	9.7	1,640	1,210	2,820	360	600	470	1,060	170	180
3	s	48	.45	4,500	7,300	1,110	1.00	13.3	1,640	1,440	3,350	320	710	470	1,070	170	160
SHIPMENT FROM DOUGLAS COUNTY, OREG.																	
1	d	68	.42	3,400	6,200	1,080	.59	11.5	2,000	1,190	2,690	300	530	420	970	....	370
2	d	101	.38	2,700	5,200	880	.48	8.9	1,280	990	2,230	340	500	400	820	210	140
3	d	93	.45	3,400	6,600	1,150	.58	15.0	2,200	1,270	3,100	370	700	530	1,070	360	360
4	d	101	.43	3,500	6,400	1,030	.70	11.9	1,900	1,200	2,560	420	570	490	910	230	200
5	d	79	.42	3,900	6,800	1,160	.78	17.0	1,970	1,340	3,120	390	640	510	1,050	320	390
6	d	60	.40	3,000	5,500	830	.63	12.8	1,460	880	2,230	400	560	460	890	270	330
7	d	68	.41	3,400	6,000	940	.70	15.2	1,800	980	2,780	400	630	480	1,070	300	340
8	d	93	.40	3,700	6,300	1,090	.71	13.0	1,770	1,180	2,680	380	520	460	970	310	300
Average		83	.41	3,400	6,100	1,020	.65	13.2	1,800	1,130	2,670	380	580	470	970	290	300
2	b	131	.37	2,500	5,100	810	.45	10.1	1,380	930	2,110	370	510	410	770	140	230
2	i	100	.39	3,200	5,500	890	.65	9.2	1,540	950	2,380	320	520	400	800	150	230
2	p	121	.41	3,300	5,500	900	.68	9.6	1,630	1,090	2,480	290	550	440	940	280	270
AVERAGE OF SHIPMENTS FROM OREGON--"D" BOLTS (WEIGHTED)																	
....	....	69	.40	3,300	6,000	1,010	.63	11.7	1,780	1,130	2,690	360	570	450	950	250	280
SHIPMENT AVERAGES FOR PREVIOUS TESTS OF MOUNTAIN HEMLOCK[4]																	
....	....	70	.42	3,500	6,000	940	.78	9.4	2,550	1,210	2,890	320	580	460	880	....	....
		54	.45	4,100	7,200	1,220	.80	9.8	2,530	1,290	3,410	440	610	540	940	....	....
NEW SPECIES AVERAGES FOR MOUNTAIN HEMLOCK																	
....	....	68	.42	3,500	6,300	1,040	.70	11.0	2,100	1,180	2,880	370	580	470	930	250	280
AVERAGES FOR WESTERN HEMLOCK[5]																	
....	....	74	.38	3,400	6,100	1,220	.57	6.8	2,480	1,630	2,990	320	520	430	810	....	....

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

[2]Specimen 1 by 1 inch in cross section.

[3]Total toughness (inch-pounds per specimen) when loaded on face indicated.

[4]USDA Technical Bulletin No. 479 (4).

[5]Wood Handbook (7).

Table 3.--Mechanical properties of mountain hemlock, air-dry (shipments from Oregon)

Tree No.	Bolt	Moisture content	Specific gravity[1]	Static bending[2]: Stress at proportional limit	Static bending[2]: Modulus of rupture	Static bending[2]: Modulus of elasticity	Static bending[2]: Work: Proportional limit	Static bending[2]: Work: Maximum load	Compression parallel to the grain[2]: Stress at proportional limit	Compression parallel to the grain[2]: Modulus of elasticity	Compression parallel to the grain[2]: Maximum crushing strength	Compression perpendicular to the 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	Maximum shearing strength	Toughness[3]: Radial	Toughness[3]: Tangential
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
		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.	In.-lb.	In.-lb.
SHIPMENT FROM HOOD RIVER COUNTY, OREG.																	
1	d	11.6	0.40	6,400	11,000	1,220	1.87	10.0	3,150	1,250	5,570	720	950	540	1,560	120	140
2	d	11.5	.41	6,000	11,300	1,280	1.58	10.3	3,170	1,290	5,720	890	1,010	600	1,740	160	150
3	d	11.6	.44	6,000	11,000	1,230	1.65	9.6	4,190	1,490	6,420	800	1,090	610	1,880	150	160
4	d	11.6	.43	6,600	11,400	1,420	1.80	9.1	3,750	1,470	6,200	690	1,000	584	1,610	140	170
5	d	11.6	.41	6,300	10,900	1,280	1.78	9.5	3,550	1,360	5,900	1,030	1,080	620	1,760	130	140
6	d	11.5	.46	7,400	13,000	1,650	1.93	9.6	4,850	1,830	7,080	980	1,130	680	1,650	170	170
Average		11.6	.43	6,400	11,400	1,350	1.77	9.7	3,780	1,450	6,150	850	1,040	610	1,700	140	150
Adjusted to--		12.0	.43	6,200	11,100	1,330	1.68	9.7	3,690	1,440	5,990	840	1,040	600	1,680	....	....
3	b	11.8	.44	6,300	11,800	1,170	1.93	12.5	2,960	1,140	5,490	910	1,160	730	1,700	120	180
3	k	11.6	.44	7,000	11,800	1,340	2.06	9.8	3,920	1,390	6,160	900	1,110	630	1,650	160	160
3	s	11.6	.48	9,100	14,900	1,540	3.24	12.2	4,840	1,680	7,640	800	1,260	660	1,580	140	140
SHIPMENT FROM DOUGLAS COUNTY, OREG.																	
1	d	12.0	.44	6,300	12,000	1,380	1.60	11.6	4,080	1,490	6,260	880	1,020	630	1,830	140	180
2	d	11.9	.40	5,600	10,400	1,230	1.52	8.6	3,120	1,260	5,510	740	850	530	1,600	110	140
3	d	12.2	.48	9,500	14,700	1,500	3.35	15.7	4,150	1,680	7,080	1,070	1,150	780	1,680	180	240
4	d	12.2	.45	6,500	11,700	1,320	1.84	11.0	2,810	1,630	6,000	1,020	980	660	1,860	110	150
5	d	11.9	.45	7,800	13,600	1,510	2.27	15.5	4,370	1,540	6,610	1,000	1,150	760	1,900	170	190
6	d	11.6	.44	6,100	12,000	1,210	1.70	13.4	3,020	1,210	5,740	890	950	630	1,970	130	200
7	d	11.8	.46	5,700	12,700	1,380	1.35	15.8	3,590	1,460	6,660	970	1,230	700	1,900	150	150
8	d	12.0	.43	7,400	12,400	1,430	2.15	11.2	3,380	1,680	6,390	680	960	600	1,720	130	160
Average		12.0	.44	6,900	12,400	1,370	1.97	12.8	3,560	1,490	6,280	910	1,040	660	1,810	140	180
Adjusted to--		12.0	.44	6,700	12,100	1,350	1.88	12.8	3,560	1,490	6,280	910	1,040	660	1,810	....	....
2	b	12.1	.40	5,300	10,400	1,140	1.41	9.9	2,810	1,180	5,160	1,040	1,040	610	1,740	100	120
2	i	12.0	.41	5,700	10,600	1,180	1.52	9.2	3,430	1,280	5,710	740	1,030	570	1,760	90	140
2	p	12.2	.43	5,700	10,900	1,120	1.60	11.8	2,950	1,410	5,690	600	1,110	600	1,810	130	150
AVERAGE OF SHIPMENTS FROM OREGON--"D" BOLTS (WEIGHTED)																	
......	......	12.0	.43	6,400	11,600	1,340	1.78	11.3	3,630	1,460	6,130	870	1,040	640	1,740	140	160
SHIPMENT AVERAGES FOR PREVIOUS TESTS OF MOUNTAIN HEMLOCK[4]																	
......	......	12.0	.45	6,200	9,800	1,120	2.02	9.2	3,880	1,470	5,920	810	1,070	630	1,170	....	....
......	......	12.0	.50	8,500	12,600	1,520	2.70	8.4	5,370	2,160	7,770	860	1,270	860	1,290	....	....
NEW SPECIES AVERAGES FOR MOUNTAIN HEMLOCK																	
......	......	12	.45	6,800	11,500	1,330	2.03	10.4	4,100	1,610	6,440	860	1,090	680	1,540	140	160
AVERAGES FOR WESTERN HEMLOCK[5]																	
......	......	12	.42	6,800	10,100	1,490	1.82	7.5	5,340	1,860	6,210	550	940	580	1,170	....	....

[1] Based on volume at test and weight when ovendry.

[2] Specimens 1 by 1 inch in cross section.

[3] Total toughness (inch-pounds per specimen) when loaded on face indicated.

[4] USDA Technical Bulletin No. 479 (4).

[5] Wood Handbook (7).

Table 4.--Variation of strength and related properties of mountain hemlock in the green condition[1]

Item	Number of specimens	Mean	Standard deviation	Coefficient of variation	Standard error of mean
				Percent	
SPECIFIC GRAVITY AND SHRINKAGE					
Specific gravity--volume at indicated moisture content	188	0.42	0.037	8.7	0.003
Shrinkage, volumetric--green to ovendry--percent	95	11.1	1.54	13.9	.16
Shrinkage, radial--green to ovendry--percent	44	4.3	.62	14.3	.09
Shrinkage, tangential--green to ovendry--percent	51	7.1	.91	13.0	.13
STATIC BENDING (FLEXURE)					
Fiber stress at proportional limit--pounds per square inch	131	3,530	832	23.6	73
Modulus of rupture--pounds per square inch	131	6,290	862	13.7	75
Modulus of elasticity--1,000 pounds per square inch	131	1,060	214	20.3	19
Work to proportional limit--inch-pound per cubic inch	131	.69	.272	39.4	.024
Work to maximum load--inch-pound per cubic inch	131	10.9	3.20	29.5	.28
IMPACT BENDING--50-POUND HAMMER					
Drop causing complete failure--inches[2]	33	30	8.6	28.3	1.5
COMPRESSION PARALLEL TO GRAIN					
Crushing strength at proportional limit--pounds per square inch	102	1,890	476	25.2	47
Maximum crushing strength--pounds per square inch	188	2,990	492	16.5	36
Modulus of elasticity--1,000 pounds per square inch	102	1,150	255	22.2	25
COMPRESSION PERPENDICULAR TO GRAIN					
Crushing strength at proportional limit--pounds per square inch	89	370	88	23.5	9
SHEAR PARALLEL TO GRAIN					
Maximum shearing strength--pounds per square inch	153	930	115	12.3	9
TENSION PERPENDICULAR TO GRAIN					
Maximum tensile strength--pounds per square inch[2]	47	330	108	33.3	16
HARDNESS--BALL TEST					
End--pounds	78	570	106	18.5	12
Side--pounds	157	460	87	18.9	7
TOUGHNESS					
Average toughness--inch-pounds per specimen[3]					
Radial	35	250	85	34.7	14
Tangential	43	270	87	32.6	13

[1]Each specimen given equal weight.
[2]Based on results of previous studies only.
[3]Based on results of this study only.

Table 5.--Comparative index numbers for mountain hemlock and other woods

Species	Number of trees tested	Specific gravity	Volumetric shrinkage	Bending strength	Compressive strength	Combined bending and compressive strength	Stiffness	Hardness	Shock resistance
Mountain hemlock	24	0.40	113	79	79	79	120	71	105
Western hemlock[1]	18	.38	120	74	85	79	145	50	73
Eastern hemlock[1]	20	.38	97	72	79	75	121	51	67
Douglas-fir (Coast)[1]	67	.45	122	90	104	96	185	58	86
California red fir[1]	17	.37	117	73	77	75	146	45	68

[1]Forest Products Laboratory Rept. 1169 (6).

lock from Alaska and Montana evaluated previously. However, since the density of the shrinkage specimens averaged lower than that of more representative strength specimens, it may be assumed that shrinkage characteristics are generally similar to those previously determined.

Several strength properties of the Oregon material average somewhat lower than either of the previous shipments when this comparison is based on green wood, but the strength properties are generally intermediate between those of the previous shipments when the comparison is based on air-dry wood. Notable exceptions are modulus of elasticity in bending, in which the averages for the Oregon material fall between those for the previous material in both the green and the air-dry conditions and modulus of elasticity in compression parallel to grain, in which the Oregon material averages lower than Alaska and Montana shipments in both the green and air -dry conditions. Another exception is maximum shearing strength, in which the Oregon material surpasses Alaska and Montana material slightly in the green condition and considerably in the air-dry condition. However, the fact that considerable difficulty was encountered in developing satisfactory shearing failures leads to some question as to how much real difference in shearing properties may be indicated by those results.

It is apparent that strength increases

associated with drying small clear specimens from the green condition to 12 percent moisture content were generally greater in the Oregon material than in Alaska and Montana material previously evaluated. However, this does not appear to be due to increased shrinkage or greater density increase, either of which would indicate more compaction of the wood for an equivalent change in moisture content.

Although there are no previous toughness data on mountain hemlock with which to compare data from this study, some interesting relationships can be observed. There is a tendency for toughness to be higher when load is applied to the tangential face of the specimen than when it is applied to the radial face. This tendency has been observed frequently in softwoods, but the difference observed in the present study is generally less than would normally be expected. On the other hand, the reduction of toughness with drying from the green condition to 12 percent moisture content is considerably greater than would be expected, even though some reduction is common under such conditions. The toughness values are not greatly different in magnitude from those developed a few years ago for a sample of Douglas-fir (1).

It is important to keep in mind in connection with references to material from Oregon, from Montana, or from Alaska, that in no case was the sample from any of those areas extensive enough to be considered fully representative of the mountain hemlock in that area. Thus, the best estimate of the strength and related properties of mountain hemlock in any part of its range would be the average values based on all of the available data as presented in tables 2 and 3.

Addition of the new data has lowered average values for many properties of mountain hemlock. The comparative data in tables 2 and 3 indicate that the species averages are generally similar to those for western hemlock. The mountain hemlock averages somewhat denser and somewhat higher in shear, hardness, and modulus of rupture in both the green and the air -dry conditions, as well as in maximum crushing strength in the dry condition, However, the mountain hemlock averages somewhat lower than western hemlock in modulus of elasticity in bending and proportional limit stress in compression parallel to the grain in both the green and the air-dry conditions, as well as in maximum crushing strength in the green condition.

Conclusions

Consideration of the results of this evaluation of the standard strength and related properties of small clear specimens of mountain hemlock from two locations in Oregon, together with comparable previous

data on material from Montana and Alaska, leads to the following conclusions:

1. Average specific gravity of the species appears to be somewhat lower than previously determined, but slightly higher than that of western hemlock.

2. Shrinkage values are similar to those previously determined for the species.

3. Average strength properties are generally somewhat lower than previously determined for the species, especially for green wood, and are generally comparable to those for western hemlock. The exception to this interspecies comparability, which may be of principal significance, is the lower modulus of elasticity of the mountain hemlock.

4. Toughness of wood at 12 percent moisture content is considerably less than that of green wood.

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