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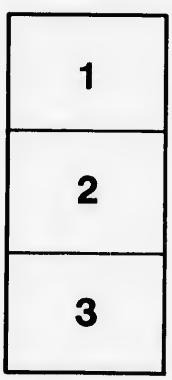

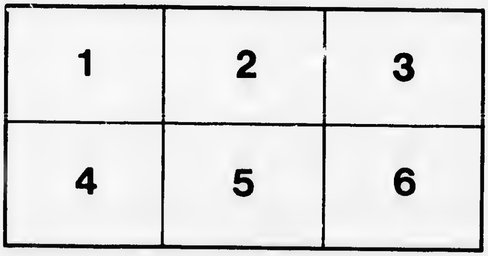

Canadian Society of Civil Engineers.
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RESULTS OF EXPERIMENTS ON THE STRENGTH OF WHITE PINE, RED PINE, HEMLOCK AND SPRUCE.

By Prof. H. T. Bovey, LL.D., D.C.L.

To be read Thursday, 11th November, 1897.

(Read before Section G, British Association, Toronto, August, 1897.)

In a paper read before the Canadian Society of Civil Engineers in 1895, the results were given of a number of experiments on the transverse strength of timber beams; but in the calculations it was assumed that the distortion, or diminution of depth, at the bearing surface was sufficiently small to be disregarded. It often happens, however, and especially when the timber contains a large amount of moisture, that the change in depth due to compression is excessive, producing a corresponding increase in the skin-stress.

This increase is theoretically $2\frac{f}{d}\Delta d$, f being the intensity of the skin-stress, d the depth, and Δd the change in depth.

The method of conducting these experiments was fully described in the Paper referred to, and therefore the following points only are noted:—

All the transverse tests were made with the Wicksteed machine. The middle of the beam was supported on a hardwood bearing of 44 ins. diameter. The two ends were forced down by rams under hydraulic pressure, which can be gradually increased at any required rate or can be maintained constant for any given time.

The end-pressures were kept normal to the surface of the beam by means of spherical joints which allow the end bearings to revolve.

The elasticity coefficients have been calculated from the following formulæ:

(*a*) Coefficients from direct tensile and compressive experiments;

$$E=\frac{L}{A}\cdot\frac{\Delta W}{\Delta L}$$

L being the length of the specimen, A its sectional area and ΔW the increment of force producing a change ΔL in the length.

(*b*) Coefficients from transverse experiments;

$$E=\frac{1}{4}\frac{L^3}{bd^3}\frac{\Delta W}{\Delta D}$$

L being the length, b the breadth, d the depth and ΔW the increment of force producing an increment ΔD in the deflection.

An error Δd in the depth theoretically corresponds to an error in E, which is approximately measured by $3\frac{E}{d}\Delta d$.

In previous experiments, the wire used in observing the deflections was found to be somewhat coarse, and a special wire was therefore drawn of .002-inch diameter.

The skin-stresses have been calculated by means of the ordinary flexure formula,

$$f=\frac{3Ly}{bd^3}(W_1+\tfrac{1}{2}W_2)$$

W_1 being the total load on the beam, W_2 the weight of the beam, and y the distance of the skin from the neutral surface.

The flexure theory is admittedly unsatisfactory, and frequently gives results which are contrary to experience. Possibly, when a certain limit has been passed there is a tendency towards equalization of stress, and the so-called neutral surface may be moved towards that portion of the beam which is best able to bear the stress. It may indeed be more correct to assume that the distances of this surface from the tension and compression faces are in the ratio of the ultimate tensile and compressive strengths of the beam. This assumption, at all events seems to give results which are more in accordance with practice. For example, in the case of a cast-iron Tee bar, tested in the University Laboratory, the tensile skin-stress should be 22,030-lbs. per sq. in., and the compressive skin-stress 102,050-lbs. per sq. in., whereas the ordinary theory gave 33,000-lbs. per sq. in. as the tensile and 20,800 lbs. per sq. in. as the compressive skin-stress.

The tables on the following pages give the breaking weights, skin-stresses, (transverse) coefficients of elasticity and specific weights of a number of air-dried, saturated, frozen and kiln-dried beams, and also the breaking weights, tensile and compressive strengths per square inch, (direct) coefficients of elasticity and specific weights of specimens prepared from these beams.

TABLE I.

WHITE PINE from ordinary stock.

No. of Beam.	Dimensions in inches.			Breaking weight in lbs.	Skin stress (f) in lbs. per sq. in.			Coefficient of elasticity in lbs per sq. in.	Sp. wt. in lbs. per cub. ft. at date of test.	Per ct. of weight lost when dried at 212° F. at			Character of failure.
	l	b	d		Max.	Min.	Mean	E		Centre.	Left end.	R't. end.	
15	186	6.225	15.2	23,850	5025	4777	4889	1,296,950	36.43	....	....	....	Crippled.
16	186	6.32	15.25	22,690	4774	4480	4627	1,359,050	38.64	....	....	....	Longitudinal shear.
28	138	9.1	15.21	39,000	4103	4018	4210	1,078,230	27.121	17.29	12.89	13.21	Longitudinal shear.
32	186	6.025	12.25	16,000	5531	5153	5342	1,368,500	27.983	28.262	27.014	27.274	Crippled.
46	186	5.725	5.9	5,200	8967	7312	8389	1,625,220	23.794	....	....	....	Crippled.

TABLE II.

WHITE PINE dried at 212° F.

No. of Beam.	l	b	d	Breaking weight in lbs.	Max.	Min.	Mean	E	Sp. wt.	Centre.	Left end.	R't. end.	Character of failure.
36	150	5.95	11.925		2201	2164	2182	1,245,780	22.007	....	....	....	Tensile.
38	75	2.965	5.925	5,000	5911	5569	5740	1,272,440	22.105	....	....	....	Crippled.
42	150	5.7	5.9	8,000	9538	9247	9392	1,282,770	20.674	....	....	....	Tensile.
43	150	6.05	11.75	23,000	9992	7091	8542	1,171,240	22.648	....	....	....	Tensile.

Beams 15 and 16 were sawn out of trees felled at Keewatin in 1894, and were received into e Laboratory on the 13th of December, their weights being 415.75-lbs. and 457.78-lbs., respectively. They were both tested on the 2nd of February, 1895, when it was found that beam 15 had lost 36.69-lbs. or 8.8 p.c. of its weight, and that beam 16 had lost 46.59-lbs. or 10.2 p.c. of its weight. When the beams were sawn through after the test they were still found to be completely saturated with water excepting for a depth of 1 inch from the surface. The beams were from the central portions of the trees, the heart running from end to end.

Beams 28 to 43 were sawn from trees felled in the water 1893-94 in Quinze Lake Co., P.Q. They remained in water one year, and were received into the Laboratory on October the 4th, 1895. They were all first quality timber, and, generally speaking, straight in grain and free from knots and shakes.

In order to determine the excess of moisture in the timber, three slabs, one near the middle and one at each end, were sawn out of the beams immediately after they had been tested and were at once placed in a chamber kept at a temperature of 212° F. by means of steam-pipes. The moisture was also removed from the whole beams by drying them in the same chamber.

Beam 36 failed suddenly under a very small load, the fracture commencing at a knot in the tension surface. On examination it was also found that the grain on the face was oblique to the neutral surface, while there were shakes running from end to end in the neighbourhood of the heart which, on the average, was below the middle of the depth of the beam. The results of this test should be discarded, as the beam was not of fair average quality.

Beam 38 was cut out of beam 36 in such manner that the grain was straight.

Beam 43 failed under a breaking load of 23,000-lbs., but a somewhat long continued and slowly increasing deflection under a load of 22,000-lbs. seemed to indicate that at this point the beam failed in compression, although there were no apparent signs of crippling.

AIR DRIED SPECIMENS FROM WHITE PINE BEAM 15.

Tension Tests.					Compression Tests.					Shearing Tests.				
Spec.	Coefficients of elasticity in lbs. per sq. in.		Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft	Spec.	Coefficients of elasticity in lbs. per sq. in.		Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of rounds.
	Forward.	Return.				Forward.	Return.							
a_1	1,749,520	1,762,500	10,490	......	e_1	....	....	2916	29.358	g_1	395.64	28.529	m_1	516.6
a_2	1,659,770	....	11,444	......	e_2	....	....	3393	27.918	g_2	447.26	27.752	m_2	505.2
b_1	1,932,560	....	15,640	......	f_1	....	....	3751	33.103	g_3	355.21	26.032	m_3	561.7
b_2	1,934,680 }	1,956,220 }	13,248	......	f_2	1,572,850 }	1,572,090 }	3604	29.025	h_1	419.19	28.409	n	598.7
	1,910,370 }	1,951,120 }				1,571,600 }	1,565,300 }			h_2	327.81	27.561	o	477.7
c	2,062,680	....	12,686	......		....	....	......	......	h_3	382.38	27.473	p	486
d	1,823,860	....	14,103	......	m	1,731,300	1,716,330	3918	28.033	i	362.75	26.655		
										j	315.24	26.122		
										k	361.26	27.541		
										l	338.11	27.226		

Remarks.—The values of E for specimens a_2, b, c and d have been calculated from the first series of readings only, and are consequently smaller than if repeated readings had been taken.

The mean direct tensile strength is 2.68 times greater than the calculated mean skin-stress of the beam and 3.7 times greater than the mean compressive strength of the timber.

Specimens e_1 and e_3 contain the heart and show the least compressive strength. The ratios of length to least transverse dimensions in the compression specimens varied from 6.47 to 9.46, and the failure in each case was due to direct crushing.

The shearing strength of the round specimens is 1.42 times greater than that of the flat specimens.

The several specimens had lost considerably in weight during the interval of their preparation from the beam and the date of test.

Tension specimen b, after the first series of readings, was entirely relieved of load and was allowed to rest for two hours.

Between the two series of readings, compression specimen f_2 remained under the load of 50,000 lbs. for sixteen hours, the final reading varying from .01117 to .01172.

AIR-DRIED SPECIMENS FROM WHITE PINE BEAM 16.

Tension Tests.					Compression Tests.					Shearing Tests.				
Spec.	Coefficients of elasticity in lbs. per sq. in. Forward.	Coefficients of elasticity in lbs. per sq. in. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity in lbs. per sq. in. Forward.	Coefficients of elasticity in lbs. per sq. in. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of rounds.
a	1,626,330	....	9,777	......	g_1	1,935 550	1,912 950	3978	.....	k_1	321.90	26.552	u	552.95
b	1,843,820	1,863,540	10,021	......	g_2	1,694,000	1,690 900	2880	32.75	k_2	405.40	25.941	v	636.74
	1,843,170	1,858,240			g_3	....	....	3978	34.157	l	321.35	25.952	w	689.113
c	1,445,900	....	5,772	......	h	1,455,090	1,449,670	4737	26.461	m	294.81	26.534	x	557.18
d	1,635,720	....	12,108	......	l_1	1,574,990	1,569.160	2963	28.668	n	375.56	26.807		
e	2,245,130	2,295,170	11,902	.....	l_2	1,560,010	1,535,620	3331	27.102	o	331.21	26.672		
f	1,652,480	....	10,884	......	l_3	....	....	2924	34.157	p	342.80	26.584		
										q	313.82	25.929		
										r	410.45	27.454		
										s	334.68	26.540		
										t	352.98	27.513		

Remarks.—The values of E for specimens a, c, d and f have been calculated from the first series of readings only, and are consequently smaller than if repeated readings had been taken.

The mean direct tensile strength is 2.21 times greater than the calculated mean skin-stress of the beam and 27 times greater than the mean compressive strength of the timber.

Specimens i_1, i_2, i_3, contain the heart, and the heart also passes along one side of specimens g_1, g_2, g_3. These specimens show the least strength. The ratio of length to least transverse dimensions was 37.1 for g_1, 26.73 for g_2, 34.157 for g_3, 24.56 for h, 27.03 for i_1 and 28.88 for i_2.

The mean shearing strength of the round specimens is 1.76 times greater than that of the flat specimens.

The several specimens had lost considerably in weight in the interval between their preparation from the beam and the date of test.

Tension specimen h was entirely relieved of load after the first series of readings, and was allowed to rest for 16 hours.

AIR-DRIED SPECIMENS FROM WHITE PINE BEAM 28.

Tension Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity.		Tensile strength per sq. in	Sp. wt. per cub. ft.	Spec.	Coefficients of elasticity.		Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
	Forward.	Return.				Forward.	Return.					
1	1,379.890	1,379.510	6,689	24.296	9	1.274,300	1,271,500	3675	24.591	a_1	336.97	25.16
2	1,313.530	1,319.840	6,377	23.51	10	1.293,370	1,298,800	3451	25.096	b_2	374.28	25.887
3	1.157.130	1.162,950	6.381	22.612	11	1.590,700	1,591,210	3187	26.129	d_1	322.11	23.473
4	1,914,310	1.933.220	12,803	......	12	1.336.050	1,325.630	4283	24.004	e_1	343.14	25.418
5	1.290.760	1.298.990	8,704	22.395						f_1	379.89	25.337
6	1,584,760	1,592.749	10,101	24.238								
7	1,368.840	1.381.870	8,402	23.053								
8	1,079,410	1.099.810	5,069	22.656								

SPECIMENS KILN-DRIED AT 212° F. FROM WHITE PINE BEAM 28.

13	2,073,150	2,072,160	13,632	......	20	1,331,010 }	1,341,750 }	6518	23.685	a_2	252.00	24.598
14	1,599,550	1,606,100	7,577	22.342		1,437,910 }	1,436,950 }			b_2	215.22	24.561
15	1,498,830	1,502.830	6,250	22.652	21	1.730,420	1,734.100	8119	24.68	c	263.18	......
16	1,390,880	1,394,000	6,966	23.261	22	1.255,400	1,252,420	5654	22.057	d_2	243.18	22 491
17	1,556,790	1.547,460	10,050	22.281	23	1,563,120	1,566,180	6108	22.167	e_2	234.27	24.047
18	1,385,880	1,385,880	9,385	......						f_2	221.78	24.616
19	1,711,630	1,703,180	7,560	......								

Remarks.—The mean direct tensile strength of the air-dried specimens was 1.9 times greater than the calculated mean skin-stress of the Beam and 2.19 times greater than the mean compressive strength.

By the kiln-drying, the mean co-efficients of elasticity were increased and the mean compressive strength was also increased more than 79 per cent. The mean shearing strength was reduced more than 32 per cent., and there was a slight diminution in the mean tensile strength.

The ratios of the lengths of the compression specimens to the least transverse dimension varied between 6.49 and 7.43, and the failure was in every case due to direct crushing.

The difference between the specific weights of the air and kiln-dried specimens was not great. The specific weight of the beam was 3 or 4 lbs. per cubic foot greater than that of the specimens.

Compression specimen 20, after the first series of readings, was left under 5000 lbs. for 42 hours, the final reading varying from .00137 to .00084.

AIR-DRIED SPECIMENS FROM WHITE PINE BEAM 32.

Tensile Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a_1	1,197,090	1,513,680	10,623	24.777	g_1	1,421,190	1,115,500	3,600	26.831	n_1	300.54	27.589
b	1,497,570	1,504,610	10,014	25.001	h	....	....	2481	26.213	n_2	327.60	27.94
c	1,706,480	1,704,480	9,931	25.855	i_1	....	....	3,338	26.444	o_1	283.27	25.30
					l_2	....	....	3,967	26.561	o_2	299.73	25.285
					l_3	....	....	3,930	26.612	p	318.58	28.034
					m_1	1,435,400	1,137,220	3,799	26.889	r	353.40	24.60
										s	321.00	......

SPECIMENS KILN-DRIED AT 212 F. FROM WHITE PINE BEAM 32.

Spec.	Forward.	Return.	Tensile strength	Sp. wt.	Spec.	Forward.	Return.	Compressive strength	Sp. wt.	Spec.	Shearing strength	Sp. wt.
a_2	1,521.220	1,530,920	8,135	20.089	g_2	1,802,430	1,800,140	[illegible]	24.112	n_3	251.62	25.549
d	2,341,150	2,363,410	10,446	......	m_2	2,074,340	2,056,860	4,040	24.701	n_4	236.06	26.047
e	1,736,510	1,746,300	9,510	24.04						o_3	269.15	24.054
f	2,123.700	2,136,510	13,065	26.602						o_4	267.63	24.518
										q	264.53	23.618

Remarks.—The mean direct tensile strength of the air-dried specimens was 2.99 times the mean compressive strength and 1.9 times the calculated mean skin-stress of the beam.

By the kiln-drying, the coefficients of elasticity were increased and the mean compressive strength was increased more than 33.6 p. c. There was also a slight increase in the mean tensile strength, but the shearing strength was diminished more than 19.1 p. c.

The ratio of the length of the compression specimens to the least transverse dimension varied between 2.02 and 10.1, and the failure was in every case due to direct crushing, excepting in the case of specimen h, in which the ratio was 20 and the failure was partly due to bending.

The injured portion was removed from specimen g, which was then re-tested after it had lost in weight 1.08 lb. per cubic foot. Its compressive strength was found to be 6733 lbs. per square inch, or 1.86 times as great as in the first test.

The difference between the specific weights of the air and kiln-dried specimens was not great. The specific weight of the beam was from 2 to 4 lbs. per cubic foot greater than that of the specimens.

DRIED SPECIMENS FROM WHITE PINE BEAM 36 KILN DRIED AT 212°F.

Tension Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a_1	1,105,780	1,108,750	6236	21.260	f_1	1,581,040	1,579,840	7185	21.546	m_1	235.10	21.806
a_2	1,408,190	1,411,440	7574	21.983	f_2	1,508,840	1,501,220	5006	21.953	m_2	215.02	22.339
b_1	1,378,040	1,385,500	3329	22.072	g	1,330,890	1,325,060	5844	20.60	n_1	272.77	22.021
b_2	1,254,210	1,260,000	4914	22.316	h	1,963,430	1,958,110	5312	20.917	n_2	239.15	21.745
c	....	....	2241	22.180	k	1,441,300	1,436,810	5589	21.416	n_3	267.28	21.931
d_1	1,124,970	1,430,630	7446	20.69	l	1,601,400	1,550,200	6013	21.236	n_4	284.43	21.774
d_2	1,045,480	1,051,080	......	......						o_1	249.85	20.742
e_1	1,205,750	1,214,470	......	......						o_2	257.53	20.687
e_2	1,278,330	1,286,250	......	......						p_1	236.73	21.148
										p_2	308.00	22.844
										q_1	215.82	20.752
										q_2	237.98	22.580
										r_1	200.48	21.173
										r_2	254.79	22.378
										s_1	254.39	21.814
										s_2	325.38	22.547
										t_1	267.94	21.342
										t_2	269.62	21.567

Remarks.—The co-efficients of elasticity, tensile and compressive strength of this kiln-dried beam are all small, possibly on account of the obliquity of the grain in the timber.

The compressive strength, however, is again much greater and the shearing strength much less than the corresponding strengths in similar air-dried specimens.

Owing to some inherent weakness which could not be determined, specimen c failed under an abnormally low load, and before the extensometer had been taken off.

TABLE III.

RED PINE from ordinary stock.

No. of Beams	Dimensions in inches. l	b	d	Breaking weight in lbs.	Skin-stress (f) in lbs. per sq. in. Max.	Min.	Mean.	Coefficient of elasticity.	Sp. wt. in lbs. per cub. ft. at date of test.	Per ct. of weight lost when dried at 212° F. at Centre.	Left end.	R't end.	Character of failure.
17	186	6.15	15.2	21,350	4531	4322	4426	1,252,700	32.279	....	....	....	Crippled.
18	180	5.75	15.0	21,730	4589	4166	4527	1,351,350	....	....	....	....	Crip'd & long. shear
31	186	5.975	12.275	23,400	7840	7469	7654	1,814,190	35.95	17.38	16.9	12.94	Longitudinal shear.
45	186	6.025	6.025	7,600	10034	9871	9952	2,768,630	37.144	....	....	....	Crippled.
49	188	5.75	11.925	22,700	5240	5100	5170	1,669,010	30.592	8.8	8.7	8.1	Longitudinal shear.

TABLE IV.

RED PINE dried at 212° F.

No. of Beams	l	b	d	Breaking weight in lbs.	Max.	Min.	Mean.	Coefficient of elasticity.	Sp. wt.	Centre.	Left end.	R't end.	Character of failure.
37	150	5.75	11.875	21,000	6160	5953	6056	2,049,430	30.972	....	....	....	Longitudinal shear.
41	150	5.885	5.925	8,800	9572	9472	9522	2,261,820	30.858	....	....	....	Tensile.
41	150	5.875	11.785	20,000	5732	5617	5674	2,219,550	34.058	....	....	....	Longitudinal shear.

Remarks.—Beams 17 and 18, containing the heart, were cut from trees felled at Keewatin in 1894, and were ordinary 1st quality timber. There were shakes in Beam 17, reaching the heart at points. The grain on the lower half of the beam was straight, but ran crosswise on the tension surface. From the time the beam was received into the Laboratory to the date of the test, a period of 57 days, the beam lost 13 p.c. of its weight. After the test a 3-inch slab was cut out, and the weight of this slab on Feb. 15th, 1897, by which time the natural drying can be considered to have been completed, was found to be 28.037 lbs. per cubic foot.

Beam 18 was tested after remaining in the Laboratory 42 days, in which time it was found to have lost 8.79 p.c. of its weight. It failed by crippling and longitudinal shear, simultaneously. The grain for about 10 inches on each side of the centre was clear, straight and free from knots.

The logs from which Beams 31 to 49 were sawn were felled in the Bonnechère district in the winter of 1894-95, and remained in the water for six months. They all contained the heart, and were ordinary 1st-quality timber.

Beam 32 failed by longitudinal shear along a shake in the neighbourhood of the neutral surface, but there were indications that this had been immediately preceded by a slight crippling.

Beam 41 was straight grained, but contained large shakes on the sides and on the compression surface due to seasoning and drying.

Beam 44 was straight grained and comparatively free from knots, but contained shakes which apparently extended from the heart outward to the sides. After remaining in the Laboratory 255 days it had lost 22.4 p.c. of its weight. A 1-inch slab cut from one end of the beam weighed, after being dried at 212°F., 30.31 lbs. per cub. ft.

Beam 45 was a dense timber of excellent quality with shakes occurring intermittently. A constantly increasing deflection indicated that crippling had taken place under a load of 7600 lbs., although the crippling was not apparent until the load was 8000 lbs.

Beam 49 was straight-grained, with a few intermittent shakes.

AIR-DRIED SPECIMENS FROM RED PINE BEAM 17.

Tension Tests.				Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
1	1,469,430 }	1,478,130 }	4,229	a_1	1,835,160	1,836,770	3,789	32.248	d	290.24	29.667
	1,466,560 }	1,466,560 }		a_2	....	....	2,958	29.541	e	160.34	31.239
2	2,124,670	2,132,680	13,253	a_3	....	....	3,757	30.988	f	192.53	27.702
3	2,273,150	2,264,000	12,808	b_1	1,222,660	1,218,430	2,684	....	g	469.93	30.356
4	2,131,060	2,180,350	13,772	b_2	....	....	2,696	26.667	h	363.35	32.69
5	1,827,060	1,824,650	8,716	c	1,265,440	....	4,421	30.394	i	484.60	33.005
6	1,403,940 }	1,442,340 }	7,782						j_1	376.53	27.281
	1,450,670 }	1,463,670 }							j_2	429.72	27.361
7	1,780,020	1,843,180	10,906						k_1	410.66	29.414
8	1,331,320	1,382,780	5,143						k_2	403.83	29.194
9	2,094,130	2,144,610	12,015						l	162.87	32.876
	2,017,040	2,041,880	5,460						m	359.61	28.08

Remarks.—The mean direct tensile strength is 2.12 times greater than the calculated mean skin-stress of the beam and 2.66 times greater than the mean compressive strength.

Specimens b_1 and b_2 contain the heart, and shew the least compressive strength. The ratios of length to least transverse dimensions in the compression specimens were 8.62 for a_1, 8.82 for a_2; 5.78 for a_3; 11.98 for b_1, 6.2 for b_2; and 5.84 for c. The failure was in each case due to direct crushing.

The average specific weight of the specimens was about 2 lbs per cubic foot less than the specific weight of the beam.

Tension specimen 6, after the first series of readings, was left under 1600 lbs. for 2½ hours, and during this interval the final reading varied from .01065 to .0111.

AIR DRIED SPECIMENS FROM RED PINE BEAM 18.

Tension Tests.

Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.
1	1 966,970	....	14,154	......
2	1,998,050	....	....	......
3	1,943,230	....	....	......
4	1,751,840 } 1 801,600 }	1,772,000 } 1,804,750 }	8,661	......
5	2,116 110	....	11,919	......
6	1,819,380	....	10,128	......
7	2,387,640	....	17.494	......
8	2,080,060	....	16,609	......
9	2,018,180	....	13,362	.....

Compression Tests.

Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.
10	....	....	3,330	12.6
11	936,987	942,214	2,789	34.667
12	1,281,810	1,295,800	3,631	35.039

Shearing Tests.

Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of rounds.
13	427.41	31.982	24	644.71
14	439.93	33.394	25	621.65
15	362.66	33.634	26	738.22
16	327 95	35.418	27	619.43
17	384.01	33.641	28	671.48
18	380.20	32.627	29	627.66
19	323.03	33.466		
20	382.88	34.474		
21	318.59	33.822		
22	293.77	34.221		
23	369.61	32.427		

Remarks.—The mean direct tensile strength is 2.84 times greater than the calculated mean skin stress of the beam and 3.93 times greater than the mean direct compressive strength.

Specimen 11 contained the heart and shews the least compressive strength.

The ratios of length to least transverse dimension were 6.43 for specimen 11, and 6.71 for specimen 12. In each case the failure was due to direct crushing.

The coefficients of elasticity for specimens 1, 2, 3, 4, 6, 7, 8, 9, were calculated from the first series of readings only, and are consequently smaller than if repeated readings had been taken.

The shearing strength of the round specimens is 1.79 times the mean shearing strength of the flat specimens.

The timber of the beam in question was unusually dense, and the mean specific weight of the beam does not seem to have been much greater than the mean specific weights of the compression and shearing specimens.

Tension specimen 4, after the first series of readings, was entirely relieved of load for 16 hours.

AIR-DRIED SPECIMENS FROM RED PINE BEAM 31.

Tensile Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity.		Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity.		Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
	Forward.	Return.				Forward.	Return.					
a_1	2,179,100	2,192,170	12,973	31.31	f_1	....	....	4,775	36.04	j_1	341.88	32.265
b	2,387,050	2,383,650	11,275	34.227	f_2	....	....	5,062	35.353	k_1	403.15	33.946
c	2,337,200	2,357,330	12,510	31.127	f_3	....	....	5,063	34.902	k_2	345.94	33.575
d	2,180,150	2,192,110	9,817	32.32	g	....	....	4,489	36.366	l_1	425.43	35.577
e	2,261,920	2,292,290	13,613	34.1	h_1	2,002,780	1,980,670	3,990	35.24			
					i_1	2,428,500	2,421,890	6,337	33.119			

SPECIMENS KILN-DRIED AT 212 F. FROM RED PINE BEAM 31.

Spec.	Forward.	Return.	Tensile strength	Sp. wt.	Spec.	Forward.	Return.	Compressive strength	Sp. wt.	Spec.	Shearing strength	Sp. wt.
a_2	2,659,930	2,677,030	10,170	32.996	h_2	1,549,860	1,510,130	6,098	32.237	j_2	222.94	30.553
					i_2	2,382,530	2,400,150	11,726	31.705	j_3	261.04	30.502
										k_3	300.86	32.021
										l_2	313.10	......
										l_3	331.00	31.945

Remarks.—The mean direct tensile strength is 1.65 times greater than the calculated mean skin-stress of the beam and 1.55 times greater than the mean direct compressive strength.

By the kiln-drying the tensile strength was diminished, the compressive strength was largely increased, and the shearing strength was diminished by 24.1 p.c.

The ratios of the length to the least transverse dimension in the compression specimens varied from 5 to 10, and in each case the failure was due to direct crushing.

Specimens h_1 and h_2 contain the heart and shew the least compressive strength in the air and kiln-dried conditions, respectively. The loss of weight in kiln-drying varied from 1.344 lbs. to 3.003 lbs. per cubic ft.

TABLE V.

Hemlock from ordinary stock.

No. of Beam.	Dimensions in Inches.			Breaking weight in lbs.	Skin-stress (f) in lbs. per sq. in.			Coefficients of elasticity.	Sp. wt. in lbs. per cub. ft.	Per ct. of weight lost when dried at 212° F.			Character of failure.
	l	b	d		Max.	Min.	Mean.						
25	222	8.815	10.1	13,000	5132	4995	5063	1,581,710	53.025	50.43	39.93	47.85	Crippled.
26	186	8.975	10.015	20,000	6615	6371	6493	1,498,640	36.533	....	....	....	Crippled.
29	186	9.85	11.95	20,040	4133	4058	4096	883,291	36.235	31.6	....	....	Tensile.

TABLE VI.

Hemlock dried at 212° F.

40	87	4.35	4.925	3,500	7946	5054	6500	1,379,860	31.346	....	....	....	Longitudinal shear.

TABLE VII.

Hemlock saturated and frozen.

22	138	9.0	11.875	30,800	5393	5166	5280	1,174,700	38.69	....	....	....	Tensile.
23	138	9.025	11.9	21,000	3482	3450	3466	1,242,150	45.23	....	....	....	Tensile.
35	190	9.175	10.05	22,000	7188	6960	7074	1,633,050	50.707	51.07	49.75	57.42	Crippled.

Remarks.—Beams 22, 23 and 35, containing the heart, had lain in the water for a considerable time, and were completely water-soaked. When tested, Beams 22 and 35 were found to be hard frozen. Beam 23 was also frozen, but not throughout, as was shewn when the beam was cut in two at the centre. Beam 22 was straight-grained, free from knots, and failed with a sudden sharp fracture. Incipient decay had commenced near the heart of Beam 23, which, however, was regarded as a fair specimen of ordinary commercial quality. It was full of large knots and the grain was curved from end to end. Beam 35 was straight-grained, clear, comparatively free from knots and of exceptionally good quality; beam 40 was cut out of beam 35 after the latter had been tested.

Beams 25, 26 and 29 all contained the heart. Beam 25 was a good specimen, and was completely water-soaked. Beam 26 was saturated throughout, excepting for a depth of $1\frac{1}{2}$ inches from surface, and, although an apparently poor specimen, was considered to be of ordinary commercial quality. It was full of knots and its grain was curved.

AIR DRIED SPECIMENS FROM HEMLOCK BEAM 22.

Tension Tests.					Compression Tests.					Shearing Tests.				
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs per sq. in. of rounds.
a_1	764,411	781,570	4,718	26.8	k_1	1,055,110	1,050,600	3,532	41.875	n_1	452.8	31.993	x	613.22
a_2	881,318	919,122	7,222	30.98	k_2	1,312,200	1,289,860	3,902	41.109	n_2	355.5	36.176		
b	1,147,350	1,159,160	7,967	29.07	l_1	1,315,040	1,284,400	3,128	42.132	n_3	350.91	39.947		
c	939,920	993,213	7,640	29.61	l_2	1,550,510	1,538,950	2,918	38.391	n_4	376.40	39.074		
d	1,086,220	1,099,860	8,468	28.70	m	1,413,050	1,110,110	3,078	36.326	o_1	317.46	38.42		
e	1,099,050	1,141,500	7,076							o_2	307.50	36.985		
f	1,123,780	1,104,380	7,418							p_1	320.04	38.915		
g	1,233,040	1,213,250	8,475							p_2	391.10	41.271		
h	....	....	7,590							q_1	368.99	......		
										q_2	371.93	43.424		
										q_3	364.54	37.558		
										r	400.94	......		
										s	387.80	......		
										t	482.17	......		
										v	519.87	......		

Remarks.—The mean direct tensile strength is 1.43 times greater than the calculated mean skin-stress of the beam and 2.31 times greater than the mean direct compressive strength. The shearing strength of the round specimen is 1.52 times greater than the mean shearing strength of the flat specimens. The ratios of length to least transverse dimension in the compression specimens varied between 5.3 and 7.27, and the failure was in each case due to direct crushing.

The compression specimens had the appearance of being frozen, but the frost in the tension and shearing specimens had thawed, although they still remained very cold and water-soaked. In fact, the specific weight of several of the specimens was even greater than the mean specific weight of the frozen beam.

AIR-DRIED SPECIMENS FROM HEMLOCK BEAM 25.

Tension Tests.					Compression Tests.					Shearing Tests.				
Spec.	Coefficients of Elasticity. Forward.	Coefficients of Elasticity. Return	Tensile strength in lbs. per sq. inch.	Sp. wt. in lbs. per cubic foot	Spec.	Co-efficients of Elasticity. Forward.	Co-efficients of Elasticity. Return.	Compressive strength in lbs. per sq. inch.	Sp. wt. in lbs per cubic ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of rounds
1	1,345,310	1,367,250	7,680		d_1	1,011,030	1,090,140	2491	51.442	n_1	393.90	51.144	x_1	537.37
2	1,585,850	1,607,759	10,553	41.34	d_2	1,477,400 }	1,465,030 }	3347	51.515	n_2	406.13	51.6	x_2	528.91
3	1,728,280	1,811,670	8,985	39.27		1,517,810 }	1,507,750 }							
4	1,826,190	1,856,350	8,079	38.61	e	1,838,000	1,841,500	....	....	o_1	369.92	45.58	x_3	619.28
a_1	2,034,780	2,091,950	13,514	57.10	f	1,576,700	1,564,290	....	48.71	o_2	407.19	47.37	y_1	663.78
a_2	1,706,210	1,753,400	9,409	50.01						p	324.12	52.547	y_2	710.86
a_3	1,668,330	1,708,410	13,000	39.39	g	1,430,680 }	1,428,860 }	3148	53.013	q_1	416.77	50.522	y_3	670.34
						1,392,550 }	1,407,390 }							
b_1	2,053,630 }	2,063,210 }	14,721	48.7	h	1,472,160	1,468,870	3420	54.754	q_2	396.79	49.172	i	670.53
	2,049,900 }	2,052,410 }								r_1	423.81	44.208	z_1	606.67
b_2	1,906,590	1,946,310	14,501	58.43	k	1,485,230	1,473,900	3140	51.741	r_2	441.02	45.47	z_2	630.67
c_1	1,704,500	1,732,610	11,759	....	l	1,411,770	1,409,290	3147	55.009	s_1	420.98	51.213	z_3	623.55
c_2	2,096,270	2,113,630	13,619	61.07	m	1,609,900	1,587,806	3714	51.503	s_2	361.48	50.388	j_1	637.80
......	....	....	....	....	......	....	....	....	....	t_1	421.20	38.38	j_2	556.29
......	....	....	....	....	......	....	....	....	....	t_2	428.80	39.791	......	....
......	....	....	....	....	......	....	....	....	....	u_1	405.09	46.268	......	....
......	....	....	....	....	......	....	....	....	....	u_2	444.95	49.975	......	....
......	....	....	....	....	......	....	....	....	....	v_1	362.48	56.402	......	....
......	....	....	....	....	......	....	....	....	....	v_2	382.13	55.526	......	....

Remarks.—The mean direct tensile strength is 2.1 times greater than the calculated mean skin-stress of the beam and 3.33 times greater than the mean compressive strength. The mean shearing strength of the round specimens is 1.59 times greater than the mean shearing strength of the flat specimens.

The ratios of the length to the least transverse dimension varied between 6.08 and 9.86, and the failure was in each case due to direct crushing. The results indicate that the tensile and shearing strengths are greatest in those specimens of the greatest specific weight.

Several of the specimens had a greater specific weight than the mean specific weight of the beam.

Tension specimen b^1, after the first series of readings, was left under 400 lbs., for 17 hours, the final reading varying from .00033 to .00017.

Compression specimen g, after the first series of readings, was wholly relieved of load for $1\frac{1}{2}$ hours.

Compression specimen d_2, after the first series of readings, was wholly relieved of load for 15 hours.

AIR-DRIED SPECIMENS FROM HEMLOCK BEAM 26.

Tension Results.					Compression Results.					Shearing Results.		
Spec.	Coefficients of Elasticity. Forward.	Coefficients of Elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec	Coefficients of Elasticity. Forward.	Coefficients of Elasticity. Return	Compressive strength in lbs per sq. in	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Spec.
	1,891,870	1,935,760	11,021	30.79	k	......	......	3652	37 02	u_1	334.06	38.40
	1,834,260	1,867,730	12,162	28.635	l	......	......	3673	35.73	u_2	285.50	38.04
	1,310,340 }	1,349,090 }										
	1,265,660 }	1,277,750 }	4,610	28.622	m	......	......	4446	37.67	v_1	363.47	31.90
	1,233,050 }	1,254,760 }								v_2	393.29	31.50
c	1,832,230	1,853,060	11,636	29.993	n	......	......	3305	40.933	w_1	315.26	32.90
d	2,024,800	2,073,450	13,974	33.288	o_1	......	......	3183	32.318	w_2	331.36	34.20
e	1,497,260	1,539,700	5,653	31.647	o_2	1,312,190	1,336,480	3057	34.016	x_1	356.90	33.89
f	1,799,240 }	1,761,660 }		......	o_3	1,736,0[illegible]0	1,754,840	4050	31.755	x_2	306.60	34.11
	1,913,660 }	1,785,440 }	11,798	......								
	1,991,910 }	1,897,400 }		......	p_1	1,457,030	1,461,250	3899	32.294		371.00	32.06
	1,927,100 }	2,007,250 }		......	p_2	899,630	912,367	2703	33.073		316.80	29.65
g	2,143,450	2,194,380	10,552	31.395	p_3	1,475,920 }	1,469,460 }					
h	1,287,420	1,314,280	8,580	31.959	......	1,141,020 }	1,135,360 }	3368	32 279			
i	2,010,210	2,013,870	13,505	30.653	......	1,433,830 }	1,435,360 }					
j	1,926,110 }	1,900,360 }	13,423	28.665	......							
	1,951,400 }	1,951,400 }			q	1,631,750	1,634,750	4173	33.785			
......	......	......	......	......	r	......	......	4050	33.859			
......	......	......	......	......	......	1,210,880 }	1,214,280 }					
......	......	......	......	......	......	1,220,716 }	1,221,270 }	4538	35.789			
......	......	......	......	......	s	1,226,920 }	1,228,050 }					
......	......	......	......	......	t	......	......	3838	35.826			

SPECIMEN KILN-DRIED AT 212° F. FROM HEMLOCK BEAM 26.

......	......	......	......	......	i	1,833,420	1,833,420	7837	30.82			

Remarks.—The mean direct tensile strength was more than 2.36 times as great as the calculated mean skin-stress of the Beam and 3.6 times greater than the mean compressive strength. The kiln-dried specimen shewed a compressive strength more than double the mean compressive strength of the air-dried specimens.

The ratios of the length to the least transverse dimensionsin the compression members varied from 2.5 to 7.8, and the failure was in each case due to direct crushing.

Between the first and second series of readings, b remained under 400 lbs. for 16 hours, the final reading varying from .00457 to .00372.

Between the second and last series of readings the specimen was left under 400 lbs. for $47\frac{1}{2}$ hours. The reading varied from .001 to .00398 in the first two hours, and the extensometer was then reset at zero. During the next hour it varied from zero to .001; and the final reading before recommencing the test was .00082. The average time occupied in each observation was about one minute. The variation in the value of the coefficient of elasticity was due to the gradua drying of the specimen, and also to the varying hygrometric condition of the atmosphere.

Specimen f was left under the load of 400 lbs. for 17 hours after the first series of readings, the final reading varying from .0033 to .01064. After the second test it was left under 400 lbs. for 23 hours, the final reading varying from .00281 to .00995. Between the third and fourth series of readings the specimen was left under 400 lbs for 5 hours, the final reading varying from .00163 to .00284. The variation of the reading was due to the gradual drying of the specimen and to the changing hygrometric condition of the atmosphere.

Between the two series of readings for specimen j there was an interval of 90 hours.

The small tensile strength of the specimen was chiefly due to the fact that the grain of the specimen was slightly oblique to the axis.

The compression specimen p_3 was left under a load of 5,000 lbs. after the first series of readings for 42 hours, the final reading varying from .00081 to .00398. After the second series of readings it remained under 5,000 lbs for 48 hours, the final reading only varying from .00401 to .00398.

The compression specimen s was left under 5,000 lbs. for 18 hours after the first series of readings, the final reading varying from .0026 to .00268. After the second series of readings it was left under 5,000 lbs. for 4½ hours, the final reading varying from .00278 to .002805.

After specimen p_2 had been tested the injured portion was removed and the remainder retested when it had lost 2.4 lbs. per cubic foot of its weight. Its compressive strength was 4,097 lbs. per square inch.

AIR-DRIED SPECIMENS FROM HEMLOCK BEAM 29.

Tension Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a	1,212,920	1,221,340	4387	25.69	e_1	1,242,410	1,241,540	3673		h_1	390.16	30.916
b	1,368,490	1,378,790	3113	27.813	f_1	......	......	2089	30.51	i_1	360.41	31.58
c	1,115,370	1,140,190	3240	25.194	f_2	......	......	2864	32.70	j_1	424.95	32.661
d	1,137,000	1,149,880	3250	26.852	f_3	......	......	1524	32.715	l	398.51	32.719
					g_1	......	......	2468	32.765			
					g_2	......	......	3354	31.146			
					g_3	......	......	3429	28.82			
					k	......	......	2311	31.50			

SPECIMENS KILN-DRIED AT 212° F. FROM HEMLOCK BEAM 29.

a_2	1,310,770 } 1,298,970 }	1,321,290 } 1,300,430 }	7022	22.473	e_2	1,190,580	1,168,060	4074	23.503	h_2	384.71	24.309
										i_2	321.20	24.364
										j_2	350.17	....
										m	285.87	24.71

Remarks.—The mean direct tensile strength is less than the calculated mean skin-stress of the beam and only 1.24 times as great as the mean compressive strength. This result is doubtless due to the fact that the timber was of very poor quality and full of knots and shakes.

By kiln-drying, the coefficients of elasticity were increased, the tensile strength was doubled, the compressive strength was increased by 18 per cent., and the mean shearing strength was diminished by 9.9 per cent.

The ratios of length to least transverse dimension in the compression members varied from 2.14 to 10.52, and the failure in each case was due to direct crushing, excepting in the case of k in which the ratio was 19.6 and which partly failed by bending.

In the case of a_2, the interval between the two series of readings, during which the specimen was left under a load of 100 lbs., was 1 hour, and the final reading varied from .00054 to .00059.

After k had been tested the injured portion was removed and the uninjured portion of the specimen was re-tested, when it failed by direct crushing under 4122 lbs. per square inch, the specific weight being 28.4 lbs. per cubic foot, and the ratio of the length to the least transverse dimension 5.2.

SPECIMENS FROM FROZEN HEMLOCK BEAM 35.

Tension Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sp. inch.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a_1	1,145,590	1,147,450	7792	40.306	h_1	1,464,480	1,449,300	4119	49.45	k_1	132.76	48.142
b_1	1,363,620	1,382,340	8694	43.822	h_2	1,655,890	1,653,610	3961	52.257	k_3	399.43	49.540
b_2	1,562,710	1,566,269	11366	36.029	h_3	....	....	4131	59.188	l_1	528.39	45.332
c_1	1,824,900	1,833,150	7521	56.112	i_1	841,150	835,046	2951	52.822	l_2	491.92	43.671
c_2	1,248,610	1,250,450	13351	48.892	j_1	1,244,060	1,222,700	3611	52.416	l_3	531.24	51.156
d_1	1,158,230	1,165,680	7580	46 719	j_2	1,440,900	1,144,010	3678		m_1	419 28	49.161
e_1	1,735,800	1,738,940	11725	48.109						m_2	517.25	52.28
f_1	1,605,600	1,666,520	10319	57.25						m_3	468.67	49.806
f_2	1,772,310	1,801,440	9487	55.226						m_4	127.35	48.655
g_1	1,311,950	1,313,760	9906	56.917								

SPECIMENS KILN-DRIED AT 212° F. FROM HEMLOCK BEAM 35.

Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sp. inch.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a_2	2,274,680	2,277,990	4613	26.901	h_4	1,566,450	1,555,800	6645	25.95	k_2	310.24	26.29
c_3	1,582,810	1,585,130	7107	27.198	h_5	1,929,030	1,925,350	8948	27.106	k_4	296.87	26.801
d_2	1,748,500	1,750,920	8073	26.323	i_2	1,379,940	1,380,230	4275	25.81	l_4	334.37	29.067
e_2	2,080,120	2,088,470	7197	28.331	i_3	1,178,510	1,173,020	4833	25.79	l_5	356.49	29.402
f_3	1,586,910	1,602,350	5903	21.210		1,479,560	1,465,030			l_6	329.90	29.201
						1,187,650	1,181,200			m_5	366.45	28.868
g_2	1,621,920	1,626,520	8650	25.135	j_3	1,496,420	1,492,730	7316	25.421	m_6	330.95	28.153
						1,494,100	1,491,620			m_7	288.53	28.448
g_4	1,615,080	1,620,220	2671	26.283		1,505,000	1,506,690					
						1,518,620	1,519,010					

Remarks.—The mean direct tensile strength of the cold and water-soaked specimens is 1.4 times greater than the calculated mean skin-stress of the beam and 2.82 times greater than the mean direct compressive strength.

By the kiln-drying the tensile strength was diminished, the compressive strength increased more than 87 p.c., and the shearing strength diminished more than 33 per cent. The coefficients of elasticity were also increased.

The ratios of the length to the least transverse dimension in the compression specimens varied between 4.43 and 5.57, and in each case the failure was due to direct crushing.

After h_2 had been tested, the injured portion was removed, and the specimen was dried at 212 ° F. and re-tested with the following results:—coefficient of elasticity=1,511,000 (forward), 1,517,830 (return); compressive strength = 7107.8 lbs. per square inch; specific weight= 27.017 lbs. per cubic foot.

After h_2 had been tested the injured portion was removed and the specimen was allowed to dry gradually in the laboratory for about a month. It was then re-tested, with the following results:—coefficient of elasticity = 1,526,200 (forward), 1,521,590 (return); compressive strength = 3636.3 lbs. per square inch; specific weight = 38.07 lbs. per cubic foot.

After j had been tested the injured portion was removed and the specimen was immediately re-tested, with the following results:—coefficient of elasticity = 1,608,560 (forward), 1,615,300 (return); compressive strength = 3592.5 lbs. per square inch; specific weight =52.02 lbs. per cubic foot.

The injured portion was removed, and the specimen dried at 212 ° F. when it was re-tested, with the following results:—co-efficient of elasticity=1,662,500 (forward), 1,657,900 (return); compressive strength =6246 lbs. per square inch; specific weight = 25.33 lbs. per cubic foot.

In the case of specimen j_1.

After 1st series of readings it was left under 20,000 lbs. for 18½ hours, the final reading varying from .00755 to .00766.

After 2nd series of readings it was left under 20,000 lbs. for 47½ hours, the final reading varying from .00678 to .00741.

After 3rd series of readings it was left under 20,000 lbs., for 3½ hours, the final reading varying from .00723 to .00726.

After 4th series of readings it was left under 100 lbs. for 17¼ hours, the final reading varying from .00149 to .0018.

After 5th series of readings it was left under 100 lbs. for 3¼ hours, the final reading varying from .00176 to .00188.

After j_2 had been tested the injured portion was removed and the specimen immediately re-tested, with the following results:—coefficient of elasticity = 1,284,450 (forward), 1,278,860 (return); compressive strength = 34,328 lbs. per square inch; specific weight = 46.61 lbs. per cubic foot.

The injured portion was removed and the specimen dried at 212 ° F. and re-tested, with the following results:—

From 1st series of readings, coefficient of elasticity = 1,496,940 (forward), 1,503,930 (return).

From 2nd series of readings, coefficient of elasticity = 1,465,810 (forward), 1,459,920 (return).

From 3rd series of readings, coefficient of elasticity = 1,471,140 (forward), 1,473,280 (return); the compressive strength = 7021.6 lbs. per cubic foot; the specific weight = 24.66 lbs. per cubic foot. Between the 1st and 2nd readings the specimen remained under 100 lbs. for about ½ hour, the final reading varying from .00043 to .00021. Between the 2nd and 3rd readings the specimen remained under 100 lbs. for about 1 hour, the final reading varying from .0007 to .00056.

TABLE VIII.

SPRUCE from ordinary stock.

No. of Beam.	Dimensions in inches. l	b	d	Breaking weight in lbs.	Skin-stress (f) in lbs. per sq. in. Max.	Min.	Mean.	Coefficient of elasticity.	Sp. wt. in lbs. per cub. ft. at date of test.	Per ct. of weight lost in drying at 212° F. Centre.	Left end.	R't end.	Character of failure.
24	222	9.175	10.1125	15,800	6208	5846	6027	1,629,050	32.307	26.7	24.7	27.3	Crippled.
27	186	8.725	10.025	14,600	4899	4758	4829	1,458,360	29.354	....	....	....	Crippled.
30	186	8.725	11.875	15,900	3758	3682	3720	2,020,300	30.603	11.1	....	....	Longitudinal shear.

TABLE IX.

SPRUCE dried at 212 F.

No. of Beam.	l	b	d	Breaking weight in lbs.	Max.	Min.	Mean.	Coefficient of elasticity.	Sp. wt.	Centre.	Left end.	R't end.	Character of failure.
39	78	3.775	4.35	5,800	9774	9603	9689	2,373,080	31.606	....	....	....	Longitudinal shear.

TABLE X.

SPRUCE saturated and frozen.

No. of Beam.	l	b	d	Breaking weight in lbs.	Max.	Min.	Mean.	Coefficient of elasticity.	Sp. wt.	Centre.	Left end.	R't end.	Character of failure.
33	186	9.2	10	14,000	7212	6887	7050	2,373,080	39.78	30.618	33.55	....	Crippled.

Remarks.—Beam 24 was wet, but was in good condition and comparatively free from knots. Beam 27 was of ordinary commercial quality, with fairly straight grain and [a large number of small knots. Beam 30 was of ordinary commercial quality, but with large shakes running from end to end and dividing the beam practically into four sections. Beam 33 was water-soaked and hard frozen when tested. It was of exceptionally good quality, free from shakes and had clear, straight grain. Beam 39 was cut out of Beam 33 after the latter had been tested.

AIR-DRIED SPECIMENS FROM SPRUCE BEAM 24.

Tension Results.

Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt in lbs. per cub. ft.
24 a_1	2,161,000	2,181,220	14,603.7	......
a_2	1,978,840	1,9[illegible]710	11,438.2 (for a_2 and the following row)	......
....	2,030,600	2,045,530		......
a_3	2,011,130	2,085,110	11,461.7	......
b_1	2,023,120	1,986,800	12,106.6	......
b_2	1,956,550	1,930,900	10,218.6	......
b_3	1,920,180	1,964,320	12,676.1	......
c	2,127,280	2,171,470	14,404.2	......
d_1	2,086,020	2,117,930	12,112.4	
d_2	2,148,920	2,175,230	11,880.3	
e_1	1,731,720	1,761,420	11,020.6	
e_2	1,872,180	1,894,110	16,906.8	
e_3	1,679,770	1,749,620	11,587.1	

Compression Results.

Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.
f_1	1,538,940	1,530,420	2781.73	32.475
f_2	1,298,130	1,299,530	2772.67	31.90
f_3	1,717,900	1,711,560	2921.41	31.38
g_1	1,551,350	1,572,860	3218.9 (for g_1 and the following row)	31.156 (for g_1 and the following row)
....	1,603,210	1,591,990		
g_2	1,568,350	1,565,470	2865.37	33.57
h	1,566,960	1,555,490	2825.98	31.165
k	1,523,240	1,524,010	3202.37	32.75

Shearing Results.

Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of rounds.
l_1	353.68	30.13	x_1	660.94
l_2	352.11	30.227	x_2	576.57
m_1	249.11	30.237	x_3	632.10
m_2	326.25	30.607	y_1	549.90
n_1	344.33	......	y_2	598.55
n_2	267.33	......	y_3	[illegible]6.94
o_1	286.79	30.538	z	598.50
o_2	302.75	30.044		
p_1	307.74	32.582		
p_2	393.70	32.750		
q_1	287.12	33.726		
q_2	315.91	32.636		
r_1	374.79	31.295		
r_2	361.36	31.666		
s_1	258.20	32.937		
s_2	285.58	31.007		
t_1	370.73	33.177		
t_2	334.28	31.987		

Remarks.—The mean direct tensile strength was more than double the calculated mean skin-stress and 4.21 times the mean direct compressive strength.

The mean shearing strength of the round specimens was 1.86 times the mean shearing strength of the flat specimens.

Tension specimen a_2, after the first series of readings, was left under the load of 1600 lbs. for 43½ hours, the final reading varying from .01243 to .01707.

The ratios of length to least transverse dimension in the compression specimens varied between 6.81 and 8.9, and the failure was in each case due to direct crushing.

Between the first and second series of readings g_1 was entirely relieved of load for 17 hours. After two repetitions of loading and relieving from load, specimen f_3 was left under 5,000 lbs. for 1½ hours, and during this interval the reading varied from .00099 to .00092.

AIR DRIED SPECIMENS FROM SPRUCE BEAM 27.

Tension Results.					Compression Results.					Shearing Results.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
1	1,383,460	1,381,220	6035.8	30.357	1	....	....	3805.9	27.07	c_1	410.72	30.865
2	1,490,440	1,500,000	8777	29.012	2	....	....	3968.4	28.498	c_2	417.30	29.90
3	1,953,260	1,963,630	14,920	27.06	3	....	....	3218.9	27.298	f_1	421.30	27.80
	1,991,850	2,007,080			4	....	....	3450.	28.881	f_2	394.95	28.16
4	1,432,120	1,439,510	9,405.2	27.121	c_1	1,477,850	1,477,070	3499	28.839	f_3	374.35	27.893
6	1,909,530	1,918,340	10,797.	26.03	c_2	1,106,850	1,109,700	3429.8	28.084	g_1	427.70	26.12
	1,174,260	1,197,320			......	1,127,900	1,126,420			g_2	357.80	26.43
a_1	1,194,130	1,198,190	7724.	31.814	d_1	2,001,680	2,000,220	3671.9	28.393	h_1	414.51	28.635
b_1	2,169,940	2,180,770	12,370	26.69	d_2	1,679,500	1,674,440	4277.6	27.034	h_2	398.73	28.546
					......	1,686,630	1,683,560					
					5	1,845,250	1,906,760	3741.1	26.791			
					6	2,011,200	2,011,200	4438.5	26.292			
					6_1	....	....	4373.0	......			

SPECIMENS KILN-DRIED AT 212° F. FROM SPRUCE BEAM 27.

a_2	1,525,080	1,541,120	6182	.....	c_3	1,565,270	1,562,420	5907.1	26.015	......	....	......
b_2	1,847,430	1,852,130	10,362	25.897	d_3	1,875,380	1,878,550	6430.2	26.152	......	....	......

Remarks.—The mean tensile strength of the air-dried specimens was more than double the calculated mean skin-stress of the Beam, and 2.67 times the direct mean compressive strength. By kiln-drying the tensile strength was diminished, and the mean compressive strength was increased more than 65 per cent.

Specimen 3, after the first series of readings, was left under 400 lbs. for 46 hours, and during this interval the final reading only varied from .00258 to .00260.

Specimen a_1, after the first series of readings, was left under 400 lbs. for 22 hours, and during this interval the final reading varied from .00378 to .00567.

The ratios of the length to the least transverse dimensions in the compression members varied between 4.23 and 8.89, and in each case the failure was due to direct crushing, excepting in the cases of specimens 5 and 6, in which the ratios were 18.76 and 14.32 respectively, which failed to some extent from bending.

Specimen c_2 between the two sets of readings, was left under 5,000 lbs. for 41 hours, the final reading varying from .00049 to .00103.

Specimen d_2, between the two sets of readings, was left under 5,000 lbs. for 41 hours, the final reading varying from .00128 to .00079.

After compression specimen 2 had been tested, the injured portion was removed and the remainder re-tested, when its specific weight was

25,965 lbs. per cubic foot and its compressive strength 4849 lbs. per square inch.

The injured portion was removed from this last, and the remainder again tested, when its weight was 26,024 lbs. per cubic foot and its compressive strength 6621.2 lbs. per square inch.

Specimens 3, c_1, c_2, c_3, all contain the heart and show the least compressive strength.

AIR-DRIED SPECIMENS FROM SPRUCE BEAM 30.

Spec.	Tension Tests. Coefficients of elasticity. Forward	Tension Tests. Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Compression Tests. Coefficients of elasticity. Forward.	Compression Tests. Coefficients of elasticity. Return.	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Shearing Tests. Shearing strength in lbs. per sq. in. of flats.	Sp. wt. in lbs. per cub. ft.
a_1	2,293,580	2,305,180	13,380	29.666	d_1	....	....	6051	32.447	g_1	375.88	32.012
b_1	2,585,260	2,629,010	22,153	30.592	c_1	....	....	6933	31.257	g_2	377.29	32.076
c_1	2,370,480	2,386,600	8,053	30.347	c_2	....	....	4986	32.005	h_1	376.51	31.18
1	2,139,190	2,151,460	12,570	30.367	c_3	....	....	7660	31.352	h_2	391.12	29.899
3	2,323,210	2,343,300	14,397	29.203	f	2,262,770	2,263,690	5183	31.076			
4	2,372,570	2,404,210	16,571	31.843								

SPECIMENS KILN-DRIED AT 212° F. FROM SPRUCE BEAM 30.

Spec.	Forward	Return.	Tensile strength	Sp. wt.	Spec.	Forward.	Return.	Compressive strength	Sp. wt.	Spec.	Shearing strength	Sp. wt.
a_2	2,759,620	2,765,020	13,932	29.571	f_2	2,243,550	2,237,150	9202	28.671	g_3	233.66	31.241
b_2	2,647,040	2,650,330	19,492	30.284						g_4	246.40	31.173
c_2	2,847,550	2,868,760	16,797	29.925						g_5	324.56	31.173
										h_3	307.21	28.729
										h_4	347.09	29.240
										h_5	303.03	29.243

Remarks.—The mean direct tensile strength of the air-dried specimens was 3.9 times the calculated mean skin-stress of the beam, and 2.35 times the mean direct compressive strength.

By the kiln-drying, the mean tensile strength seems to have been increased, but specimen c_1, failed under an abnormally small load, probably because of some inherent weakness. The compressive strength was increased 77 per cent., and the mean shearing strength diminished more than 22 per cent.

The ratio of the length of d to its least transverse dimension was 20.925.

The ratios of the length to the least transverse dimension in the remainder of the compression members varied between 2.06 and 10.1, and in each case the failure was due to direct crushing.

WET AND FROZEN SPECIMENS FROM SPRUCE BEAM 33.

Tension Tests.					Compression Tests.					Shearing Tests.		
Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return.	Tensile strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft.	Spec.	Coefficients of elasticity. Forward.	Coefficients of elasticity. Return	Compressive strength in lbs. per sq. in.	Sp. wt. in lbs. per cub. ft	Spec	Shearing strength in lbs. per sq. in. of flats	Sp. wt. in lbs. per cub ft.
a_1	2,219,660	2,273,580	16,202	36.213	1.	1,813,380	1,833,110	3403.4	38.019	g_1	287.76	36.027
b_1	2,268,750	2,261,770	15,610	37.209	2.	1,780,710	1,786,120	3347.7	38.07	g_2	301.05	36.017
b_2	2,233,170	2,211,170	7234.3	43.092	f_1	2,088,870	2,096,050	3535.0	36.859	h_1	490.94	36.876
c_1	2,115,850	2,127,810	10,681	37.945						h_2	444.27	37.758
d_1	2,026,110	2,057,910	12,115	40.629						h_3	437.32	39.957
e_1	2,199,660	2,505,910	12,605							k_1	367.65	35.122
m_1	1,963,180	1,964,210	15,151							k_2	409.78	36.292
n_1	2,025,160	2,027,170	15,686	38.706						k_3	425.72	38.756
										l	430.58	38.285

SPECIMENS KILN DRIED AT 212° F. FROM SPRUCE BEAM 33.

Spec.	Forward.	Return.	Tensile strength	Sp. wt.	Spec.	Forward.	Return	Compressive strength	Sp. wt.	Spec	Shearing strength	Sp. wt.
a_2	2,971,210	2,992,750	9453.8		f_2	2,975,120	2,971,780	6571.8	33.302	g_3	291.11	30.817
b	2,511,630	2,516,310	9728.6	32.27						g_4	278.81	29.612
c_2	2,689,700	2,704,750	19,168	32.711						h_4	379.78	31.648
c_3	2,833,350	2,872,170	9592.3	32.213						h_5	379.56	31.643
d_2	2,641,050	2,651,570	12897.	33.563						k_4	371.86	29.704
e_2	2,489,330	2,496,680	18,678	30.356						k_5	381.23	30.952
m_2	3,452,309	3,173,810	8713.7	30.07								
m_3	2,802,680	2,810,900	20,780									
n_4	2,266,790	2,278,640	13,226	31.816								
n_5	2,252,020	2,254,870	18,384	28.507								
o	2,768,130	2,789,900	17,910	30.836								

Remarks.—The mean direct tensile strength of the saturated specimens was nearly double the calculated mean skin-stress of the beam and 3.88 times the mean compressive strength.

By the kiln-drying, the tensile strength seems to have been slightly increased, the compressive strength was increased 80 per cent. and the shearing strength was diminished more than 12 per cent. The coefficients of elasticity were also increased.

The ratios of the length to the least transverse dimension in the compression members varied from 4.07 to 5.85, and failure was in each case due to direct crushing.

After compression specimen 1 had been tested the injured portion was removed and the remainder re-tested, when its specific weight was 37.457 lbs. per cubic foot, its coefficient of elasticity 1,627,890 (forward) and 1,634,960 (return), and its compressive strength 3700 lbs. per square inch. The injured portion was removed from this last, and the remainder was dried at 212° F. and then tested with the following results:—

Coefficient of elasticity from 1st series of readings
= 2,402,710 (forward), 2,400,340 (return).

Coefficient of elasticity from 2nd series of readings
= 2,415,620 (forward), 2,411,810 (return).

Coefficient of elasticity from 3rd series of readings
= 2,419,940 (forward). 2,421,360 (return).

Between the first and second readings the specimen was under 100 lbs. for 3 hours, the final reading varying from − .00005 to + .00002. Between the second and third readings the specimen was left under 100 lbs. for 25 minutes, the reading varying from − .00005 to + .00002. The specific weight of the dried specimen was 32.559 lbs. per cubic foot.

After f_1, had been tested the injured portion was removed and the remainder retested, with the following results :—

Coefficient of elasticity = 1,972,390 (forward), 1,962,020 (return); compressive strength = 3521.4 lbs. per square inch; specific weight = 36.777 lbs. per cubic foot.

After 2 had been tested the injured portion was removed and the remainder re-tested, with the following results :—

Coefficient of elasticity = 1,733,480 (forward), 1,727,000 (return); compressive strength = 3736.7 lbs. per square inch; specific weight = 37.602 lbs. per cubic foot.

The injured portion was removed from the last and the remainder dried at 212° F., when it was tested, with the following results :—

Coefficient of elasticity = 2,690,130 (forward), 2,699,970 (return); compressive strength = 8465 lbs. per square inch; specific weight = 30.253 lbs. per cubic ft.

Specimen 2 contained the heart, and shews the least compressive strength.

Remarks on E.—It may be observed that the coefficient of elasticity and strength often differ widely in value, even in the case of specimens which were in the same alignment in the original beam, and which had been treated, as far as practicable, in a precisely similar manner. This may be due to a number of uncontrollable causes, as, for example, an inherent weakness or a want of parallelism in the grain, but it is certainly largely due to the proportion of moisture present in the specimen and perhaps to some but a much smaller extent, to a variation in the temperature.

Again the difference between the means of the forward and return observations diminishes as the moisture is eliminated, and as the material approaches the normal state, that is, the state in which it contains the greatest amount of moisture consistent with the hygrometric condition of the surrounding atmosphere. The same is true also of kiln-dried specimens, but the latter, on account of their small section, rapidly absorb moisture until the normal state is reached. The rate of loading was kept as uniform as possible, the average time per reading being ½ minute for tension and ¾ minute for compression specimens. The following examples will serve as illustrations :—

A.—SPECIMEN OF WHITE PINE MARKED 1. (KILN-DRIED).

This specimen was taken out of the kiln on March the 28th, 1895, and allowed to cool in the Laboratory during the night.

Its sectional area = .7288 square inches, and its specific weight = 21.788 lbs. per cubic foot.

Date.	No. of readings.	Mean forward reading.	Mean return reading.	Temp. (Fah.) of Laboratory.	Mean pressure of vapour.	Mean relative humidity.	Dew point.
Mar. 29	96	691.702	698.572	28.8 to 30.1	.2		
" 30	30	699.113	699.267	45.3 to 46.8	.2152	88.3	36.2
" 30	54	705.153	704.463	68.1 to 68°3	"	"	"
" 31	40	688.342	688.175	67.4 to 68°	.1793	87.3	31.5
Apr. 1	50	673.958	673.6	33 to 37°5	.1082	83.0	19.7
" 2	30	686.5	686.066	67° to 68	.470	93.7	30.3
" 3	20	685.111	685.3	64.5	.1173	88.7	22
" 4	29	670.65	670.25	34.5 to 37.8	.1202	89	22.2
	26	669.5	669.5	33 to 35.3			
" 7	30	682.5	682.	64 to 67.8	.1557	89	28.3
" 8	30	678.857	678.228	65.2	.1498	86	27.3
" 9	34	666.469	666.147	35°	.1382	80	25.3
" 9	15	676.643	676.143	61°5		71.7	

Tensile strength of specimen = 12,294 lbs. per sq. inch.

B. SPECIMENS OF RED PINE MARKED GI. (KILN-DRIED).

SPECIMEN 1.—Sect. area = .6874 sq. ins.; sp. wt. = 30.9 lbs. per cub. ft.; tensile strength = 14,620 lbs. per sq. in.

SPECIMEN 2.—Sect. area = .71775 sq. ins.; sp. wt. = 33.17 lbs. per cub. ft.; tensile strength = 12,023 lbs. per sq. in.

SPECIMEN 1.

Date.	No. of readings.	Mean forward reading.	Mean return reading.	Temp. (Fahr.) of Laboratory.	Mean pressure of vapour.	Mean relative humidity	Dew point.
Mar. 28	14	654 3/4	654 3/7	55° to 64°	.0945	85.0	17.0
" 29	48	649.28	649.56	28° to 30°			
" 29	25	650.32	650.	25°5 to 27			
" 30					.2152	88.3	36.2

SPECIMEN 2.

Date.	No. of readings.	Mean forward reading.	Mean return reading.	Temp. (Fahr.) of Laboratory.	Mean pressure of vapour.	Mean relative humidity	Dew point.
Mar. 27	22	605.9	64.72	33°	.082	86.5	13.3
" 28	42	600.625	600.309	27 5	.0945	85.0	17.0
" 28	21	617.65	616.95	65			

Again, a kiln-dried tension specimen, with a sectional area of .658 square inches, was placed in the testing machine on April the 10th, 1896, and was subjected to a load which was gradually increased up to 1000 lbs. Under this load, the extension during the first day was at the rate of 6.1 hundred-thousandths of an inch per hour. On every succeeding day this rate diminished, but irregularly, until the test piece had reached its normal state. At this point, the slightest change in the humidity produced a corresponding change of length in test piece. The maximum amount of extension, viz., .00708 inch, occurred on the 11th of May.

The greatest observed rates of extension and recovery per hour were 7 and 8 one hundred-thousandths of an inch, respectively. On the 16th of May the load was reduced to 200 lbs., when the extension was also reduced to .0024 inch. One hour later the reading had fallen to .00233 inch, but an increase in the humidity then caused a corresponding increase in the extension of .00017 inch.

In the transverse experiments the greatest possible care was taken to increase the load at the same uniform rate, the average time occupied in adding each increment and in taking the corresponding reading being slightly greater than 1 minute. In many cases the beam was loaded, then relieved of load, and reloaded again, the readings in all cases being carefully noted. This operation was sometimes repeated more than once. Whenever a beam or a specimen under tension or compression was subjected to repeated loadings, the first series of readings were almost invariably discarded as the increments of deflection, and changes of length were found to be more uniform *after* the preliminary loading. The initial loading seems to eliminate certain inequalities of resistance.

In Beam 15 there was an increment of .401 in. in the deflection, corresponding to an increment of 7,000 lbs. in the load. On reducing the load to 500 lbs., there was an apparent set of .006 in., which would have undoubtedly disappeared in a very short time. Upon re-loading the beam the increment of deflection for the same increment of load was .4 inch.

In Beam 17 the increments of deflection under the first and second loadings were exactly the same, viz., .415 inch for an increment of 7,000 lbs. in the load. When the load, after the first series of readings, was reduced to 500 lbs., there was an apparent set of .005 inch, which would have certainly disappeared had the beam been allowed to rest for a few minutes.

In Beam 24 (Spruce) for an increment of 6,000 lbs. in the load, the increment of deflection was 1.04 in. in the first loading and 1.034 in.

in the second. Upon being entirely relieved of load, there was an apparent, but evidently only apparent, set of .01 in.

In Beam 25 (Hemlock), for an increment of 6,000 lbs. in the load, the increment of deflection was 1.165 in. in the first loading and 1.155 inch in the second, the apparent set when entirely relieved of load being .01 inch.

In Beam 27 (Spruce), after being loaded and then entirely relieved of load, there was an apparent set of .005, which in two hours had fallen to .002 inch.

In Beam 26 (Hemlock), after being loaded and then entirely relieved of load, there was an apparent set of .004 inch which had entirely disappeared after an interval of about two hours.

In the case of Beam 28 (White Pine) there were three sets of loadings, the increments of deflection corresponding to an increment of 12,000 lbs. in the load being:—

.238 in. and .234 in. for the first set,

.237 in. and .232 in. for the second set,

.237 in. and .232 in. and .232 in. for the third set,

When the Beam was entirely relieved of load after the first set, there was an apparent set of .002 in., which had entirely disappeared in 25 minutes. The second set of loadings commenced after an interval of 18 hours. The mean increment of deflection = .2344 in.; the mean compression = .0827 inch, and, using the ordinary formula, the corresponding value of $E = 1,066,980$ lbs.

The increments of deflection for repeated loadings corresponding to an increment of 6,000 lbs. in the load were:—

.675 in., .660 in., .650 in. for Beam 29 (Hemlock),

.335 in., .330 in., .337 in. for Beam 30 (Spruce),

.492 in., .485 in., .487 in. for Beam 31 (Red Pine),

.675 in., .655 in., .653 in. for Beam 32 (White Pine),

.313 in., .308 in., .305 in., .306 in. for Beam 49 (Red Pine).

The increments of deflection for repeated loadings, corresponding to an increment of 7,000 lbs. in the load, were:—

.625 in., .620 in., .620 in., .625 in. for Beam 33 (Spruce).

The increments of deflection for repeated loadings, corresponding to an increment of 5000 lbs. in the load, were:—

.590 in., .556 in., .555 in. for Beam 35 (Hemlock).

For beams dried at 212° F., the increments of deflection for repeated loadings were:—

.420 in., .400 in., .405 in., .405 in., .405 in. for Beam 36 (White Pine) and an increment of 6,000 lbs.

.178 in., .173 in., .173 in. for Beam 37 (Red Pine) and an increment of 4,000 lbs.

.039 in., .042 in., .040 in., .040 in. for Beam 38 (White Pine) and an increment of 300 lbs.

.048 in., .048 in., .048 in., .049 in. for Beam 39 (Spruce) and an increment of 300 lbs.

.071 in., .070 in., .070 in., .070 in. for Beam 40 (Hemlock) and an increment of 300 lbs.

.363 in., .358 in., .358 in., .363 in. for Beam 41 (Red Pine) and an increment of 1,200 lbs.

.669 in., .672 in., .675 in. for Beam 42 (White Pine) and an increment of 1,200 lbs.

.411 in., .416 in., .408 in., 402 in. for Beam 43 (White Pine) and an increment of 6,000 lbs.

.243 in., .240 in., .238 in., .241 in. for Beam 44 (Red Pine) and an increment of 6,000 lbs.

From these results and from the further observations up to the point of fracture, the following inferences may be at once drawn:—

(*a*) The increment of deflection diminishes and therefore the co-efficient of elasticity increases with the elimination of the moisture from the beam.

(*b*) The increments of deflection are much more uniform in amount in the case of kiln-dried beams.

It is, of course, impossiblo to maintain a beam in a kiln-driod state. As soon as it is exposed to the atmosphere, it at onoe commences to absorb moisture, and the absorption continues until thero is an equilibrium between the hygrometric conditions of the boam and atmosphere. The beam is then in its normal state, and the experiments indicate that the incremonts of deflection, corresponding to this state, are approximately uniform. The rate of absorption depends essentially upon tho nature of the timber, and proceeds more slowly as the density increases. The weight of a central 2 inch slab of beam 30 (spruce) increased 3.6 per cent. in 24 days and 8.5 per cent. in 47 days.

The influence of moisture on the deflection of a beam was well illustrated in the case of 15 inch x 6 inch Douglas fir beam on 186 inch centres. On June 15th, 1895, it was placed in position and was loaded with a weight of 1000 lbs. at the centre, producing a deflection of .071 inch. The daily observations, extending over several months, showed a continually increasing deflection, until, by the evaporation of the moisture, the beam had attained its normal state. The average deflection now remained constant, varying, for example, hetween .09 inch on August 24th, and .082 inch on September 2nd, the greater deflection of course corresponding to an increase of moisture in the atmosphere. On the 4th of September, the load was increased to 2000 lbs., which produced a deflection of .127 inch. This load remained on the beam until January 8th, 1896, the deflection during the same period varying between .129 inch and .114 inch.

Changes of temperature produced no appreciable effect upon the deflection, but its sensitiveness to the presence of meisture is shown by the following table of daily observations, taken at 12 p.m., from August to December.

UNDER A LOAD OF 1,000 LBS. DURING AUGUST.

Temp.	Def.	Remarks.	Temp.	Def.	Remarks.	Temp.	Def.	Remarks.
72°5	.080		75°3	.089	Cloudy and showery.	70°4	.085	Dull, cold and showery.
73°5	.080		74°9	.088	Cloudy.	70°6	.090	Continuous rain.
71°8	.081		74°0	.088	Fine.	72°2	.089	Showery, then fine.
73°0	.083		75°9	.088	"	72°5	.089	Fine.
75°0	.083		76°7	.086	"	73°8	.089	"
74°1	.088		76°4	.088	Stormy.	74°6	.089	"
73°0	.087		75°3	.088	"	71°3	.089	Dull and cool.
75°0	.087		73°5	.086	"	75°5	.082	Fine.
75°8	.087		72°0	.086	Fine and showery	74°9	.086	Showery.
74°9	.088		70°8	.085	Dull, cold and showery.			

UNDER A LOAD OF 2,000 LBS. DURING SEPTEMBER.

Temp.	Def.	Remarks.	Temp.	Def.	Remarks.	Temp.	Def.	Remarks.
77°3	.127		71°0	.129	Cloudy and cold.	71°3	.126	Fine and warm.
76°9	.129	Cloudy.	68°75	.129	"	77°3	.126	"
56°2	.129	"	58°0	.125	"	71°5	.128	Fine, but cooler.
77°0	.129	Rain.	69°5	.126	Fine and warm.	71°0	.126	"
75°8	.126	Fine and stormy.	66°0	.124	Fine and cold.	71°6	.128	Wet and stormy.
75°3	.126	Stormy.	69°4	.121	Fine and warm.	70°0	.128	Fine.
75°0	.129	Cloudy.	69°0	.125	"	67°1	.128	"
						65°8	.126	"

UNDER A LOAD OF 2000 LBS. DURING OCTOBER.

Temp.	Def.	Remarks.	Temp.	Def.	Remarks.	Temp.	Def.	Remarks
65°0	.127	Dull, cold and showery.	75°0	.123		68°0	.118	Fine and cold.
68°0	.125	Fine and warm.	65°8	.123	Stormy.	68°0	.116	" "
68°5	.125	" " "	64°3	.126	"	61°8	.119	Damp and cold.
66°2	.125	" " "	66°0	.120	Fine and cold.	63°5	.116	Fine and cold and dry.
66°0	.125	" " "	66°4	.120	" "	65°0	.114	" "
65°0	.125	" " "	67°0	.122	" "	65°0	.115	" "
70°0	.125	Dull and cold. Laby. heated.	65°8	.120	" "	68°0	.115	" "
67°0	.125	Dull and cold. Laby. heated.	68°5	.120	" "	69°0	.111	" "
			60°0	.120	" "			
			65°0	.120	" "			
			66°2	.120	" "			

UNDER 2000 LBS. DURING NOVEMBER.

68°5	.115	Rain.	66°0	.120	Cloudy and cold.	62°0	.118	Cold. Laby. heated.
70°0	.114	Cloudy and cold.	69°0	.119	" "	66°0	.115	Snow. " "
58°6	.114	Fine and cold.	68°5	.119	Fine and cold.	57°8	.120	Fine.
65°0	.115	" "	69°0	.119	Rain.	60°0	.115	Snow.
67°8	.115	" warm.	70°3	.119	Fine and warm.	67°5	.118	Rain and warm.
68°0	.115	" "	63°7	.120	Fine.	69°7	.118	Cloudy & warm.
66°3	.120	Rain and warm. Laby. door open.	66°0	.120	Dull and wet.	69°0	.118	Fine and warm.
60°0	.120	" " "	67°5	.120	Rain and warm.	69°3	.118	Fine.
53°0	.120	Continuous rain.	68°0	.120	Cloudy and warm	70°0	.115	Fine and cold.
57°0	.122	Snow & freezing.	59°0	.120	Snow and cold.			
58°0	.120	Cloudy and cold.						

UNDER 2000 LBS. DURING DECEMBER.

Temp.	Def.	Remarks.	Temp.	Def.	Remarks.	Temp.	Def.	Remarks.
60°	.115	Fine and cold.	62°6	.115	Fine and cold.	56°5	.115	Warm and dull.
62°5	.115	Snowstorm.	62°5	.114	" "	66°0	.115	" fine
64°5	.115	Fine and cold.	65°3	.114	" "	59°8	.120	Dull and cooler.
61°0	.114	" "	58°0	.114	" "	64°0	.120	" "
68°0	.115	" "	67°0	.114	Warm and rain.	61°5	.120	" "
62°5	.115	Snow and milder.	67°0	.115	" "	63°0	.120	" warm.
61°5	.115	" "	67°4	.115	" "	64°5	.120	" "
6[illegible]°0	.115	" fine.	67°9	.115	Warm and fine.	65°0	.120	" "
62°3	.115	Fine and cold.						

Remarks on f.—It will be observed that of the 20 non-kiln dried beams, 11 failed by crippling on the compression side, 6 failed by longitudinal shear, and 3 hemlock beams only failed by the fracture on the tension side. The experiments on the direct tensile and compressive strength of the timbers show that this is precisely what might be expected to take place. In every case the direct tensile strength is very much greater than the direct compressive strength, and failure by crippling is likely to take place under a load much less than the material could bear in tension. Under all circumstances, therefore, in practice, it is advisable to place a beam so that the portion of the timber which is strongest and in the best condition should be in compression. Again, the experiments conclusively show that kiln-drying enormously increases the direct compressive strength, but greatly diminishes the shearing strength, while the direct tensile strength does not appear to be much affected, although in the majority of cases it was diminished, and sometimes considerably.

The large increase of strength in compression due to kiln-drying might have been naturally expected, as in the process of drying the walls of the cells are stiffened and hardened, and thus become better able to resist a compressive force. The walls, however, are at the same time much more brittle, and it is possible that a sudden blow might cause the failure of a kiln-dried column, which would have remained uninjured had the moisture not been eliminated. It may also be of interest to note that in the re-tests of specimens after the injured portion had been removed, the compressive strength was, almost without exception, increased.

Hence, by kiln-drying a beam its compressive strength is made to approximate more closely to its tensile strength, and its transverse strength is consequently sometimes considerably increased. It must be remembered, however, that this kiln-drying invariably largely diminishes the shearing strength, and therefore proportionately increases the tendency to shear longitudinally. Thus, of the nine kiln-dried beams in the preceding tables, only *one* failed by crippling while *four* failed by fracture on the tensile side and *four* failed by longitudinal shear. Indeed, generally speaking, kiln-dried beams will fail either by a tensile fracture or by a longitudinal shear, and this result has been further verified by experiments subsequent to those referred to in the present Paper.

In practice, of course, beams cannot be maintained in a kiln-dried state, but they rapidly pass into the normal state. The question of how far it is desirable to eliminate the moisture depends essentially on the balance to be maintained between the tensile, shearing and compressive strengths, and a beam should always be placed so as to exert its relative strengths to the best advantage. Kiln-drying, unless some special method of prevention is adopted, develops shakes in the timber and causes existing shakes to become more pronounced. Some of these shakes often extend to a great depth and run the whole length of the beam, so that it not unfrequently happens that only a slight layer is left to hold the beam together. Such a beam, although otherwise sound and clear, offers very little resistance to longitudinal shear, and might more justly be regarded as being made up of two or more superposed beams.