TABLE IV.

Kind of wood.	Percentage moisture.	Pounds per square inch.	Percentage moisture.	Pounds per square inch.
Shagbark hickory	58	1,080	9.8	2,717
Sugar maple	56	870	12.5	1,755
White oak	78	1,004	11.4	1,685
Rock elm	46	696	11.2	1,603
Yellow birch	72	439	10.5	1,340
Black oak	80	802	11.4	1,246
White ash	47	801	11.2	1,292
Beech	61	605	13.0	1,185
Red oak	80	807	11.9	1,100
Tamarack	52	480	11.0	1,080
Red pine	54	358	12.5	833
Western yellow pine ..	125	326	9.7	805
Lodgepole pine	46	364	11.0	779
Douglas fir	32	427	12.0	744
White pine	75	314	9.9	757
Eastern hemlock	129	420	9.5	726
Red spruce	31	322	12.9	531
White spruce	41	262	12.6	455
White cedar	55	288	11.2	389

Shearing With the Grain.—Shearing strength refers to the force required to push a piece of wood in the direction in which its fibres run, and has its practical application in the strains exerted on mortise and tenon structures. The lighter conifers and hard woods shear more easily than the heavier kinds, and the best of pine from one-third to one-half as easily as hickory or oak. Surfaces parallel to the annual rings shear more easily than those parallel to the pith rays and green wood about one-third as easily as dry wood. Table V. shows the shearing strength of ten well known woods which have been kiln dried and contain specified percetages of moisture.

TABLE V.

Kind of wood.	Percentage of moisture.	Shearing force (pounds per square inch).
Shagbark hickory	9.6	2,290
Bitternut hickory	9.7	2,048
White oak	12.1	2,165
Black oak	11.6	2,005
Red oak	11.2	1,845
White ash	10.8	1,522
White elm	10.8	1,447
Red pine	12.5	1,262
White pine	9.9	1,072
White cedar	11.2	902

Hardness.—From the carpenter's point of view, hardness refers to the resistance of the fibre of wood to axe, saw, chisel or plane, and will depend upon such factors as density, moisture content, etc. Wide rings in oak and narrow rings in pine increase the hardness; heartwood is harder than sapwood; and, dry wood is harder than green wood—excepting willow and poplar. The static test for hardness used to be to note the number of pounds pressure per square inch required to force a square die into the wood to a depth of one-twentieth of an inch, but as this included shearing across the grain for two edges of the die and shearing along the grain for the other two edges the method now adopted is to record the number of pounds pressure required to force a steel ball .444 inches in diameter into the wood a distance equal to half its own diameter. Such tests show that wood is harder in an endwise direction than it is across the grain. Partly for this reason, but mainly because the endwise crushing strength of wood is much greater than its crushing strength across the grain, it is customary to set paving blocks on end.

Table VI., for the hardness of 16 well-known woods, exhibits, in a rather striking manner, how very much harder any kind of well-seasoned wood is than the same material as it came from the tree.

TABLE VI.

Kind of wood.	Percentage moisture.	Pounds pressure required to imbed a .444 inch ball to ½ its own diameter. Endwise.	Sidewise.
White oak	62	1,087	1,048
	12.8	1,520	1,487
Sugar maple	57	992	910
	10.3	1,942	1,346
Yellow birch	72	827	754
	10.3	1,542	1,280
Rock elm	46	954	888
	11.2	1,593	1,257
Beech	61	1,012	908
	13.1	1,463	1,217
Black oak	80	847	795
	11.4	1,598	1,208
Black ash	77	566	544
	11.6	1,101	792
Tamarack	52	401	375
	11	725	636
Douglas fir	32	415	406
	12	723	616
Red pine	54	355	342
	12.5	696	596
Red spruce	12.9	648	510
White spruce	12.6	526	494
Lodgepole pine	44	288	312
	11	503	533
White pine	74	304	296
	9.9	611	469
Western yellow pine	98	310	314
	11.6	546	408
White cedar	55	321	226
	11.2	466	338

Tension Along the Grain.—The tensile strength of straight-grained wood is very high and hard to measure because of the difficulty of preventing the ends of the test pieces from slipping in the shackles of the testing machine. However, it is not often that a wooden beam is used for a tie bar. For rock elm the tensile strength along the grain is approximately 28,000 pounds, or 3.8 times its endwise crushing strength; for shagbark hickory 32,000 pounds, a ratio of 3.4; for tamarack 19,400, or 2.5; and for long-leaf pine 17,300, or a ratio of 2.2 to 1. Hence, in a general way, we may say the tensile strength of the tougher woods is approximately three times their endwise compression strength.

The tests of most interest to the architect and the engineer are those for cross-bending, crushing and shearing. Long before the timber would give way in tensile strength the bolts or connections would shear through the ends of the timber, and for this reason it is customary to place them at least three or four inches from the ends of the beam required to bear tensile stress.

Torsional Strength.—The torsional strength of wood refers to the ability of its fibres to withstand twisting and is measured by securely fastening one end of the rod at one end of a lathe and clamping the other end in a wheel which can be rotated until the fibres of the wood are completely twisted and torn asunder. Hickory, rock elm, blue beech and willow possess this property in a marked degree.

Flexibility.—This property depends upon the toughness and cohesive force of the woody fibres, the percentage of moisture present, the temperature and the amount of natural or artificial impregnation. Wood from the base of the tree is more flexible than that obtained higher up, and hardwoods are generally more flexible than conifers. For all kinds of wood, moisture and heat soften