Recent Work in Wood Physics.

By William Kendrick Hatt.

(Abstract.)[1]

The new series timber tests of the Forest Service, which constitutes the most important recent series of experiments, was begun in 1902 under the direction of Mr. Gifford Pinchot, Forester, Forest Service, United States Department of Agriculture. About 44,000 test pieces have been tested.

These timber tests are divided into two parts: Class (a). Tests on market products of actual size, in which characteristic defects occur, such as stringers, vehicle parts, railroad ties, of interest and value to engineers and manufacturers. These correspond to tests on riveted joints or built-up structures in metal testing. Class (b) includes so-called "scientific" tests of small, perfect specimens with uniform moisture content, representing material collected from the forest, in which the strength is related to the physical structure and position in the tree. These tests are of especial value to the botanists and foresters and aid the solution of silvicultural problems.

A summary of results obtained to date will be presented.

Influence of Conditions of Tests upon Results.

(In these studies small, perfect specimens are used).

1. *Speed of Test.*—The strength of wood varies significantly with the speed at which stress is applied. increasing more rapidly as the speed increases. Tests are standardized for speed[2] on the basis of fiber strain per unit of time; and experimental factors obtained to adjust strength values from one speed to another. The adopted standards of fiber strain are as follows, expressed in inches per inch per minute:

Large beans	.0007
Small beams	.0015
Compression parallel to grain, small pieces	.003
Compression parallel to grain, large pieces	.0015

[1] Abstracted from paper by the author, read before the Copenhagen Congress of the International Society for Testing Materials.

[2] See Proceedings American Society for Testing Materials, Vol. 8, 1908, page 541. "The Effect of the Speed of Testing upon the Strength of Wood and the Standardization of Tests for Speed," by H. D. Tiemann.

Strength of wet or green wood is much more sensitive to changes of speed than is dry wood. At the speed adopted for official tests a change in speed of 50% may ordinarily be allowed without causing a variation in strength of over 2%.

2. *Temperature.*—Since wood is a more or less plastic substance it is sensitive to changes of temperature. Tiemann's[3] experiments show that soaking certain species in water at normal temperature does not affect their strength. It appears, however, that warm water has a marked weakening effect. The extreme condition is when wood is made pliable by boiling. Some woods are no doubt more sensitive than others to the effect of temperature of the water in which they are immersed. In recent tests made in winter weather on red oak (Quercus Rubra) ties at Purdue Uuiversity, ties taken from the temperature of the storehouse (about 25° F.) were from 9 to 17 per cent stronger than those tested at the temperature of the laboratory (about 70° F.). Probably this marked difference in strength is to be found only in case of green or wet wood. The rupture work is not affected to the degree of the ultimate strength. Hickory seems specially sensitive to change of temperature. It is concluded that the ordinary temperature variations of the air of a laboratory are not important, but that the temperature of the storehouse may render it necessary to warm the wood. In fact, the effect of a given factor on the strength of timber, or difference of strength of two species, may at times be entirely masked by variations of temperature of timber at the time of test.

3. *Moisture.*—The effect of moisture on the strength of wood has been thoroughly investigated by Tiemann.[4] His material was small test pieces uniform in moisture content throughout the cross-section; and he determined the distinct "fiber saturation" point, above which increased moisture content did not affect the strength of timber and below which there was an increase of strength. Previous experiments, yielding a continuous moisture strength law, were apparently made with "case-hardened material."

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[3] Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness of Wood," by H. D. Tiemann.

[4] Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness fo Wood," by H. D. Tiemann.

Circular 108, Forest Service, 1907. "The Strength of Wood as Influenced by Moisture," by H. D. Tiemann.

RELATION OF TESTS.

The relation between the strength under various kinds of tests, such as shear, bending, etc., and compression parallel to the grain, have not been determined yet by an analysis of the data. It is doubtful if any one test can be used to predict the strength of the material under other forms of tests when conditions vary with respect to previous heat treatment, moisture, drying or preservative treatment. For instance, brittleness induced by overheating is evident in impact tests, but this will not necessarily be evident from the compression test parallel to the grain.

An investigation of the effect of speed of test is a part of the general study of behavior of wood under three conditions of loading:

(a) Dead or constant load.

(b) Ordinary static test with increasing load.

(c) Impact test.

(a) Dead load tests exhibit the plasticity of wood. Nearly all deformations increase with duration of load, but the deformed beams subsequently tested show no loss of ultimate strength. Deflection brought about by humid atmosphere is not recovered by subsequent drying. The question is often asked: "What per cent of the load, as determined by the ordinary static test, will break a beam if left on indefinitely?" This has no answer.

(c) Under impact loading, wood will submit to greater elastic deformation than under the ordinary static tests. Impact bending tests show elastic deformation largely in excess of those experienced under static load. The impact test is made under increasing height of drop.[5] The order of resistance of air dry woods at the ultimate failure strength, so far obtained is as follows:

Hickory, Longleaf Pine, Douglas Fir, Loblolly Pine, Chestnut, Spruce, Yellow Poplar, Western Yellow Pine, Western Hemlock, Sugar Pine, and Coast Redwood.

(d) *Abrasion Test.* The abrasion test is under study.[6] Wood is worn by sand-paper in the Dorrey Machine.

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[5] Circular 38, Revised, Forest Service. "Instructions to Engineers in Timber Tests," by W. K. Hatt.

[6] See American S. for T. M., Vol. 7, 1907. "P. U. Impact Testing Mach.," by W. K. Hatt.

INFLUENCE OF TREATMENT PREVIOUS TO TEST.

(a) Drying in Hot Air, Steam, Saturated Steam, etc. A research is under way to investigate the safe limits and the most advantageous conditions for the commercial processes of drying wood. The immediate strength after drying is of course usually greater because of the lessened moisture content. It is now apparent, however, that all processes of drying wood, even air-drying, are attended with weakening of structure, so that when the dried wood is resoaked there is a loss in strength of 10%, and generally more. The drying of white ash (Fraxinus americana,), for instance, at 145° F. in either dry air or exhausted steam, or in superheated steam at 312°, caused no significant loss in strength in the air dry condition, but the resoaked wood was considerably weaker than the green wood. Under 20 to 30 pounds of steam applied during 1 to 4 hours, pine and ash suffer but little loss in static strength after the moisture from the steam is removed by air drying. At higher steam pressures (above 50 lbs.) large and permanent losses result. An equal amount of dry heat is less injurious to wood than moist air or saturated vapor, whenever the temperature exceeds 212° F. The hygroscopicity of the wood in the air-dry condition is reduced by the process of drying in steam, dry-air or saturated steam. Microscopic study shows that the cell walls split open because of the shrinkage of these walls when they begin to dry out.

The results from the Drying-Strength Study are not sufficiently advanced to allow complete conclusions.

(b) *Treatment with Preservatives.* Tests at the Louisiana Purchase Exposition[7] established the safe limit of steaming for seasoned loblolly pine to be 30 lbs. applied for 4 hours, or 20 lbs. applied for 6 hours. Burnettized loblolly pine ties exhibited some degree of brittleness under impact test. Creosote appeared to act upon the strength in the same way as water. It retards the seasoning of timber, with beneficial results to its physical condition. Present evidence points to steaming, or effect of heat in preliminary seasoning, as the only dangerous element of the treating process. The proper limits of heat should be determined for different species of timber.

In the case of bridge timbers, of coniferous species, of large size, incomplete evidence indicates that the desired penetration of creosote can

[7] Circular 39, Forest Service. Experiments on the Strength of Treated Timber," by W. K. Hatt.

only be obtained by cylinder processes that reduce the strength of the timber. The unit stresses used in the design of creosote structures should, therefore, in these cases, be decreased below standards established for natural wood.

UNIT STRESSES FOR DESIGN.

The relation of strength of large sticks, involving defects, to small and perfect pieces, taken from the parent beam, is reported in Circular 115, Forest Service. The strength of large and small sizes is not a question of geometrical magnitude, but of the existence of defects in the large sticks such as knots, shakes, checks and the presence of inferior growth.

Study has been given to the failure of large beams under longitudinal shear. It is apparent that, in the case of large beams of seasoned timber, the failure is due to longitudinal shear rather than to bending. In green beams, also, this form of failure is frequent. Therefore, shearing stresses should be taken account of in the design. The result of later tests confirm the early results that the strength of large pieces is not increased by subsequent seasoning, except in case of select grades. In other words, unit stresses for design should usually be based upon strength of green timber.

NEW SPECIES AND SUBSTITUTES.

The eucalypts of California and the South have been tested. They are among the strongest of our woods. The quality of the various species differs greatly, varying in kiln dry state from 25,000 pounds per sq. in. to 13,000 pounds per sq. in. in modulus of rupture. Tests have been completed on tan-bark oak, which formerly was left stripped of its bark in the woods.

GENERAL STUDIES OF SPECIES.

Tests of red gum are completed.[8] Tests of various species of hickory collected from various site conditions have been made and the report completed. These latter tests established relations between rate of growth and strength, locality and strength, and species and strength. It appears that the most fundamental factor governing the strength of wood of any species is the specific gravity, or, in the conifers per cent of summer wood.

[8] Bulletin No. 58, Forest Service. "The Red Gum," by Alfred K. Chittenden.

Technical Problems.—The study of track fastenings, including common and screw spikes, and tie plates, and the relation of these to the strength of ties is in progress. Laboratory tests are supplemented by service tests in tracks of railroads under operation.

TECHNIQUE OF TESTS AND THE ORGANIZATION OF THE LABORATORY WORK.

The methods and records and organization are now well developed. The results of experience for the past six years are contained in Circular 38, (Revised), entitled "Instruction to Engineers in Timber Tests." Recently a department of microscopic examination of wood has been added to study manner of failures in the tissues, changes in structure resulting from heat treatment, location of preservative fluids and allied problems.

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