TESTS ON THE PHYSICAL PROPERTIES OF TIMBER.

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OUTLINE OF TIMBER-TESTING WORK IN EUROPE.

From the beginning of the eighteenth to the middle of the present century investigations of the strength of wood received more or less attention, principally from French scientists. Owing to the limited scale upon which the work was done and to the rather crude methods employed, the results were necessarily contradictory and unsatisfactory. In 1848 Chevandier and Wertheim published the results of tests they had made on timber of the Vosges Mountains. This was the first case in which a fairly good history and description of the test material was given, and their results are even now in use.

Most of the modern work in timber testing is founded on that of Dr. H. Nördlinger, chief forester at Hohenheim, Württemberg. The results of his investigations were published in 1860. Among the most important tests of recent years are those made by Bauschinger and published at Munich in 1883 and 1887. These tests were made on Scotch Pine and Spruce from the Black Forest, and special attention was given to the conditions under which the timber grew. The main object of the work was to determine the influence of forest conditions and the time of felling on the strength of the wood. In the publication of 1883 the following statements are made, modified by the clause that they should be taken as a near approach to the truth only:

1. Stems of spruce or pine which are of the same age at equal diameters, and in which the rate of growth is about equal, have the same mechanical properties (when reduced to the same moisture contents), irrespective of local conditions of growth.

2. Stems of spruce or pine which are felled in winter have, when tested two or three months after the felling, about 25 per cent greater strength than those felled in summer, other conditions being the same.

Bauschinger, in his publication of 1887, further modifies these statements and admits that a great many more tests must be made in order to prove their truth. He agrees in general with Hartig, however, that good conditions of growth produce a good quality of wood.
OUTLINE OF TIMBER-TESTING WORK IN THE UNITED STATES.

In America the most extensive work in timber testing has been done by the Division of Forestry of this Department, and by Mr. T. P. Sharples, in connection with the Tenth Census.

TESTS IN THE TENTH CENSUS.

The tests made for the Tenth Census were very comprehensive, and included work on 412 species; they were not intended, however, to be of practical applicability as accurate data for the strength of the various species. As Mr. Sharples says, "The results obtained are highly suggestive; they must not, however, be considered conclusive, but rather valuable as indicating what lines of research should be followed in a more thorough study of this subject."

TESTS BY THE DEPARTMENT OF AGRICULTURE.

The timber tests made by the Division of Forestry of this Department were begun in 1891 and interrupted in an incomplete state in 1896. The laboratory work was carried on under the supervision of Prof. J. B. Johnson, at St. Louis, and the material was collected from the forest itself with special reference to the conditions under which it was grown. The results, therefore, are of value not only as giving data for the strength value of various woods, but also as indicating the effect of different conditions of locality on the quality of the timber. The tests include 32 species, with 308 trees, furnishing 6,000 test pieces and material for over 45,000 tests; 20,000 pieces were used for physical examination, to determine structure, character of growth, specific gravity, moisture conditions, and other properties. The principal part of the work was done on Southern pines—Longleaf, Cuban, Shortleaf, and Loblolly. Tests were also made on the following species: White Pine, Red Pine, Spruce Pine, Bald Cypress, White Cedar, Douglas Spruce, White Oak, Overcup Oak, Post Oak, Cow Oak, Red Oak, Texan Oak, Yellow Oak, Water Oak, Willow Oak, Spanish Oak, Shagbark Hickory, Mockernut Hickory, Water Hickory, Bitternut Hickory, Nutmeg Hickory, Pecan Hickory, Pignut Hickory, White Elm, Cedar Elm, White Ash, Green Ash, and Sweet Gum. Of these, the greatest number of tests were made on Bald Cypress, White Oak, Cow Oak, Overcup Oak, and Spanish Oak.

Dr. B. E. Fernow, under whose direction the tests were made, makes the following statement in regard to the work:

As will be observed, some species, like the Southern pines, have been more fully investigated, and the results on these (published in Circular 12, Division of Forestry) may be taken as authoritative. With those species of which only a small number of trees have been tested this can be claimed only within limits and in proportion to the number of tests.

Data are given in Circular No. 15, Division of Forestry, for all these species in the following kinds of tests: Compression endwise, bending
at rupture, bending at relative elastic limit, compression across the grain, and shearing with the grain. The results obtained are in all cases reduced to 12 per cent moisture contents. This was assumed to be the "highest average moisture contents of seasoned wood."

Among other special tests the following were made:

1. Effect of "bleeding" on Longleaf Pine. The results indicated that the strength was not affected.

2. Influence of size of the beams on strength. The results indicated that large beams "may be as strong as the small sticks cut from them."

3. Influence of size in compression members. The results indicated "that columns may be as strong as small compression pieces, and when weaker the presence of internal defects probably accounts for the difference."

4. To ascertain the effect of hot-air treatment in dry kilns. "The results indicate no detrimental effect, contrary to common opinion."

Tests at the Massachusetts Institute of Technology.

Prof. G. Lanza, at the Massachusetts Institute of Technology, has done a considerable amount of timber-test work, and in 1894 published his results in Applied Mechanics. Tests were made on a limited number of Yellow Pine and White Oak columns and spruce pillars and compression tests on White Pine and Yellow Pine posts. Transverse tests to determine the breaking load, modulus of rupture, and modulus of elasticity were made on beams of the following species: Yellow Pine, 52 beams; White Oak, 36; White Pine, 37; Hemlock, 17.

In addition, a series of "time tests" were made on spruce and Yellow Pine; the weights were allowed to remain on the beams for periods of from one month to over a year. From these time tests Professor Lanza draws the conclusion that "the deflection of a timber beam under a long-continued application of the load may be two or more times that assumed when the load was first applied." Professor Lanza is strongly in favor of using sticks of merchantable sizes for testing material as against small pieces. In regard to tests on small pieces he says:

While a great deal of interesting information may be derived from such tests as to some of the properties of the timber tested, nevertheless such specimens do not furnish us with results which it is safe to use in practical cases where full-size pieces are used. Inasmuch as these small pieces are necessarily much more perfect (otherwise they would not be considered fit for testing), having less defects, such as knots, shakes, etc., than the full-size pieces, they have also a far greater homogeneity. They also season much more quickly and uniformly than full-size pieces. In making this statement, I am only urging the importance of adopting in the experimental work the same principle that the physicist recognizes in all his work, viz, that he must not apply the results to cases where the conditions are essentially different from those he has tested.
In addition to the investigations mentioned above, timber tests have been made on a small scale in various parts of the country, but owing to lack of system and omission of important details they have but little practical value. Tests on the Southern pines are in a more complete state than those of other species, but it may be stated as a whole that there are to-day no reliable data at hand on the strength of the principal merchantable timbers of the United States. In other words, there are no figures on the strength and durability of American woods which an engineer feels fully justified in applying to his practical work.

TIMBER-TESTING WORK PROPOSED BY THE DEPARTMENT OF AGRICULTURE.

From the foregoing, it is evident that there is an urgent need for reliable data on the strength of American timbers; it is also plain that such data should be obtained according to an exhaustive and systematic plan. Although in many instances wood is being replaced by metal, the former will always hold an important place as a material for constructive and other purposes, and as the supply of timber diminishes, as it is rapidly doing, it becomes more and more necessary to determine its true value, so that it may be used to the greatest economic advantage. There is evidence to show that many of the species which are now classed as "inferior" may with safety take the place of timbers in common favor at the present time. No accurate data whatsoever exist as to the strength of timbers of the Pacific slope; and as these are becoming more and more important and will form the great source of supply in the future, it is desirable that their strength and durability be accurately determined at the present time.

THE INVESTIGATIONS PLANNED.

The Bureau of Forestry of the Department intends to resume the work of timber testing and to conduct the tests on a large scale, in order that the work may eventually include all the principal species of the country. The aim is to obtain results of the greatest practical value to engineers and others directly interested in the utilization of timber. The work will be divided into several series, as follows:

Series I: Tests on timber collected from the open market.

Series II: Tests on timber collected from the forest.

Series III: Tests to determine the effect of moisture and volatile oils on the strength of timber.

Series IV: Tests to determine the effect of preservatives on the strength and durability of timber.

Series V: Tests to determine the effect of kiln-drying methods.
END SECTIONS OF BEAMS FROM LONGLEAF PINE, PHOTOGRAPHED BEFORE TESTING.
BEAMS FROM LONGLEAF PINE.

[No. 1, Large timbers, photographed before testing, 10 by 12 inches by 16 feet; No. 2, break in a large beam after cross-bending test; No. 3, lines of rupture in small beams after cross-bending test.]
Series VI: Tests to determine the effect of the time rate of application of load on the mechanical properties of timber, including impact tests.

This is an exhaustive programme and can be carried out only after many years of work; the results obtained, however, will be fully worth the time and labor.

Results of practical value are expected in the immediate future from Series I, and these tests will be undertaken for the purpose of furnishing reliable data within a short time on the most important species now in common use. Specimens for testing will be purchased in the open market without special regard to the conditions under which the trees grew, and the locality from which they came will be mentioned in a general way only, as "from Berkeley County, S. C.," or "from Lewis County, Wash." It is often impossible to determine the botanical species from an examination of the manufactured timber; in many cases several distinct botanical species are sold under one market name. In this series of tests, therefore, the names of species will be given only so far as practicable, and only those distinctions will be drawn which can be made by the engineer or inspector in practice.

In the tests of Series II, "on timber collected from the forest," there will be no difficulty, of course, in determining the species. The work in connection with these tests will be more difficult and occupy more time than that of the former tests, and will not begin until the Bureau of Forestry is in a position to undertake the work in a thorough manner. This will be an investigation of the greatest importance, and especially of great practical value to the owners of timber lands. A tree is a living thing, and therefore wood, even of the same species, has a much greater variation in strength than iron or other metals. The strength of iron or steel depends upon the manner in which it is manufactured, whereas the strength of wood depends largely upon the conditions under which it grew. By noting such facts as the density of the stand, the nature of the forest mixture, the position of the tree in the forest, and the character of the locality and soil, a relation will be obtained between the strength of the timber and the conditions of growth. The physical properties of the wood also differ according to position in the tree, and this must also be considered. Such an investigation will therefore be of great service to practical forestry, for it will show under what conditions the best quality of timber is produced.

"The effect of moisture and volatile oils on the strength of timber," Series III, is one which will require careful study. It has been found in former tests that timber when moist may be 50 per cent weaker than when comparatively dry. All test material must therefore be reduced to a common degree of moisture contents, and in the case of many species the volatile oils must also be taken into account. For this purpose a method is under consideration which reduces the disks (to
be tested for moisture contents) to shavings. These shavings are placed in an iron retort surrounded by a steam jacket, and through them is passed a current of steam which carries off the volatile oil to a condenser, where it is separated from the water and weighed. To determine the total volatile matter, shavings from the same disk are dried in vacuo until the water is driven off, a stream of dry air being passed through to carry off the volatile matter. From the total volatile matter thus obtained the volatile oils as determined by the first process are deducted, the remainder being the moisture.

Methods of treating wood with various preservatives with a view to prolonging its life are now in common use and are becoming of greater importance every day. But little is yet known as to the effect which such treatment has upon the strength of the timber, and therefore the tests in Series IV will be of particular interest. There is also much difference of opinion about the effect of kiln-drying, and this matter will receive careful attention in Series V.

In Series VI static tests will be made at different time rates of application of loads on large timbers, and both static and impact tests will be made on small selected sticks, of the material and size, for instance, used in carriage manufacture.

In all the tests made according to this general plan special emphasis is to be laid upon the description of the material. There is a wide variation in the quality of timber of any one species, and therefore investigations which do not consider the defects of each stick tested have but little value. All the large beams are photographed on the four sides and both ends, and after testing, a view is taken of the break. (See Pls. LXIX and LXX.) In addition to this a written description of each stick is also made, and the imperfections, amount of sapwood, and rate of growth are noted.

The tests are made at several stations in different parts of the country, and all the work is done according to a uniform plan arranged by the Washington laboratory.