BULLERTIN NO. 556; MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES, SEPTEMBER 15, 1917

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER September 15, 1917

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By

J. A. NEWLIN, in Charge of Timber Tests
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Forest Products

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CONTENTS.

PURPOSE OF THE STUDY.

This publication on the mechanical properties of wood makes available for general use data which will serve as a basis for (1) the comparison of species, (2) the choice of species for particular uses, and (3) the establishment of correct working stresses.

The increasing scarcity of many species of timber which had become more or less standard in various wood-using industries is opening the field for other species. Through long use the properties which make the standard species valuable for a particular purpose are quite well understood, but it is doubtful if many manufacturers know to what extent other species possess those same qualities and to what extent they might replace the standard species. Present conditions will not permit long, tedious, and expensive experiments with commercial forms to establish new species in the industries; and to avoid this it is necessary to have definite information and data on both the new and the old species. With such test data at hand it is possible to compare the properties of a known species with those of any other. The possibility of substitution generally reduces to the few species which possess qualities approaching those previously in use. If the

properties making a particular wood valuable for a certain purpose are known, the comparison is made the easier.

As an example of the foregoing, suppose it is desired to find a wood for flooring for use in the place of maple. For flooring, hardness is the ruling factor, providing, of course, the wood possesses other strength properties to a reasonable degree. Using hardness as a basis for comparison, white oak should be as good or better than maple for flooring, which is true. Using modulus of rupture, which is a very important strength value in structural material but of very little importance in flooring, as a basis for comparison, longleaf pine or Douglas fir would unjustly be given preference to oak.

In addition to their value in expediting the search for substitute woods, the data presented in this bulletin are of use to manufacturers and others in furnishing definite information concerning the properties of all commercial woods. This information is used in many different ways, several of which are briefly discussed in the following paragraph.

In the preparation of specifications and grading rules for structural timber it is essential to know the relation between physical and mechanical properties, and the results of the tests here reported have been used by a number of associations and societies in preparing such rules. They are also used by architects and engineers in determining safe working stresses for wood in structures, in connection with tests upon full-sized members. In the case of new uses for wood, which frequently arise in special constructions, such as airplanes, for instance, these data are of much help in selecting the species which have the specific properties best fitting them for these uses.

In order to cover the ground successfully, this bulletin must furnish information on all mechanical properties of wood; and with that end in view no effort has been spared in making a complete compilation of the information at hand. There are few uses of timber where at least some of the properties given in the table are not of importance.

The Forest Service tests are standardized and the data contained herein on any one species are directly comparable with similar data on any other species listed. These tests obviously eliminate a great amount of duplication which would result from individual investigations. Industries anxious to find new species to supplant waning supplies of present material would doubtless make tests adapted to their own particular purpose which would probably throw no light on other properties valuable for uses not in their line. In many cases the tendency would be to keep secret such findings in order to meet more effectively competition from other firms; and even though the data from all such individual tests were available, an intelligent comparison of species could not be made because of the lack of standardization of methods of test.

SCOPE AND METHOD OF EXPERIMENTS.

ORIGIN OF DATA.

The data in this bulletin are based upon about 130,000 tests, probably the greatest number ever made in one series upon any material. For this reason, and for others explained later, the data are the most thorough and accurate that are available on the mechanical properties of American woods. The tests were begun about six years ago at the Forest Products Laboratory, which is maintained by the United States Forest Service with the cooperation of the University of Wisconsin. One hundred and twenty-six species of wood have been tested, and it is planned to continue the series until all species which are important, or which give promise of becoming so, have been included.

SMALL CLEAR SPECIMENS USED.

Small clear specimens are used in the tests in order that consideration of the influence of defects may be eliminated from calculations to determine the relation between strength and density, moisture, locality of growth, soil conditions, etc. These various relations are referred to in the present bulletin, however, only when it is necessary in order to render the data thoroughly understandable. The specimens are 2 by 2 inches in cross section. Bending specimens are 30 inches long; others shorter, depending on the kind of test.

SELECTION OF MATERIAL.

The material for any given species and locality is cut from typical trees, usually five in number. These are selected by representatives of the Forest Service, careful descriptions being made of each tree and of the conditions under which it has grown. As a rule the test specimens are taken from the top 4 feet of the 16-foot butt log. The number of test specimens from each tree varies from 40 to 120, depending on the size of the tree. Eventually each important species will be represented by tests from at least five typical trees from each of several localities distributed throughout its range of growth.

OTHER DATA INCLUDED.

Data derived from tests previously made by the Forest Service and under practically the same conditions as the present series are included in Tables 1 and 2. The tests were made at Purdue University and at the Universities of Colorado, California, and Washington in cooperation with those institutions.

TESTS ON LARGE TIMBERS.

A large number of tests have also been made by the Forest Service on full-sized timbers, such as bridge stringers, factory-building timbers, and car sills. These tests have demonstrated the influence of defects such as knots, shakes, and checks on strength, and they serve

as a guide to the use of data from tests on small specimens in establishing working stresses and grading rules for structural timbers. The results of tests of this kind on a number of species have already been published. (See list of publications, p. 46.)

PRECAUTIONS TO BE OBSERVED IN THE USE OF THE DATA.

Careful attention must be given to the natural variability of timber in order to make correct use of timber-test data. The following suggestions are offered as a guide to the use of the data given herein. Definitions of the various technical terms, with illustrations, are given on pages 7 to 18.

COMPARISON WITH DATA IN OTHER PUBLICATIONS.

In comparing the data in this publication with those in other publications, it must be kept in mind that scarcely any two series of tests have been made under the same conditions and that very frequently so little is specified concerning the character of the material and the methods of test as to make close comparisons impossible. A specific instance is furnished by the results of Sargent's tests[1] and those given in Forest Service Circular 15. These two publications are chosen as illustrations because of the numerous attempts which have been made to compare the figures in them with each other and with those obtained under the present series. Sargent made about 2,700 tests on 300 species of American woods; but he did not take into account what may have been relative large variations in moisture content, and he selected his specimens from the lower end of the butt logs—in most cases the best although most variable portion of the tree. The lack of data upon moisture content is an insurmountable barrier to comparison with the present series, since differences of moisture content between two groups of tests may be sufficient to cause as much as 100 per cent difference in the strength data. Circular 15, "Summary of Mechanical Tests on Thirty-two Species of American Woods," containing the results of about 30,000 tests, takes moisture into consideration, but allows of no comparison with the present series because of the selection of material with defects as found in the tree. Since no record of the extent or position of these defects in the test piece are now available, no estimate can be made as to the strength of the clear wood.

Data from other publications of the Forest Service which are known to be strictly comparable to those obtained from the present series of tests are included in Tables 1 and 2. The reader is cautioned against any attempt at the comparison of the data in this publication with those in any previous one dealing with tests on small clear pieces.

[1] Made for the Tenth United States Census, and results published in Vol. IX of the Tenth Census Reports.

Also, in making comparisons, it is important that the data should really be representative of the classes of material which it is proposed to compare. For example, it is not just to take the figures derived from Rocky Mountain Douglas fir, which is known to be inferior to the Pacific coast type,[1] as representative of the coast fir. Nor in general can a comparison of species properly be made from results of tests on large timbers alone; for in practically all cases the large timbers tested have not been selected as representative of the species, but have been chosen to determine the effect of defects, the effect of preservative treatment, or for the solution of other and similar problems.

Comparisons should not be made with greater refinement than the data justify. The change which additional tests would probably make in the average values and the probable variation of a given stick or lot of material from these average values should be considered. Numerical measures of these probable variations are given in Table 3.

CAUSES OF VARIATIONS IN STRENGTH.

Variations in strength of timber can be accounted for more accurately than is usually supposed. In some species there is a difference in strength in wood from different positions in the tree, different localities of growth, etc. But such variations have been overestimated, and a knowledge of them is not essential in order to estimate with a fair degree of accuracy the properties of a piece of timber. Differences in strength are usually due to differences in defects, moisture content, or density, or to combinations of these.

Defects are not considered in this publication. Their effects on structural timbers are discussed in Forest Service Bulletin 108; and limitations on their size, character, and location are given in the grading rules for structural timber which have been recommended by the Forest Service.[2]

Differences of moisture content cause considerable variation in the strength values of air-dry or partially air-dry material, but have no effect as long as all material is thoroughly green.

One of the principal factors causing differences in strength is variable density. As might be expected, the greater the density of a given stick or the more wood it has [3] per unit volume, the stronger is the stick.

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[1] See also "Localities Where Grown," p. 8.

[2] See "Discussion of the Proposed Forest Service Rules for Grading the Strength of Southern Pine Structural Timbers," by H. S. Betts, Proceedings of Am. Soc. for Test. Materials, Vol. XV, 1915, p. 368.

[3] Accurate determinations made at the Forest Products Laboratory on seven species of wood, including both hardwood and coniferous species, showed a range of only about 4½ per cent in the density of the wood substance, or material of which the cell walls are composed. Since the density of wood substance is so nearly constant, it may be said that the density or specific gravity of a given piece of wood is a measure of the amount of wood substance contained in it.