THE ELASTIC PROPERTIES OF WOOD

Young's Moduli, Moduli of Rigidity, and Poisson's Ratios of Yellow Birch

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UNITED STATES DEPARTMENT OF AGRICULTURE
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Madison, Wisconsin
In Cooperation with the University of Wisconsin

THE ELASTIC PROPERTIES OF WOOD[1]

Young's Moduli, Moduli of Rigidity, and Poisson's Ratios of Yellow Birch[2]

By

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Summary

This report presents values for the Young's moduli, the moduli of rigidity, and the Poisson's ratios of yellow birch at about 13 percent moisture content. A table is presented showing individual values and species averages of Young's moduli, the ratios E_R/E_L and E_T/E_L, and Poisson's ratios for 10 specimens (representing 6 or 7 logs) oriented in each of the 3 principal planes of elastic symmetry. Individual and average values are listed for the 3 moduli of rigidity, representing 9 flat plates oriented in the direction of each of the 3 principal planes, but all taken from a single tree. Since the number of specimens of each type was insufficient, and the tests were conducted at only one moisture equilibrium, the effect of specific gravity and moisture content on the elastic constants could not be determined.

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[1] This report is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available.

[2] This report is the ninth of a series of reports presenting the elastic properties of wood. Previous reports have included data for balsa and quipo (Forest Products Laboratory Report No. 1528), Sitka spruce (Reports Nos. 1528-A and 1528-B), mahogany and khaya (Report No. 1528-C), Douglas-fir (Reports Nos. 1528-D and 1528-E), sweetgum (Report No. 1528-F), and yellow-poplar (Report No. 1528-G).

Introduction

Tests have been conducted at the Forest Products Laboratory to determine the elastic constants of a number of wood species used in aircraft, and to correlate them with density and moisture content. This report is the ninth of a series on the elastic properties of wood and presents data for yellow birch. Previous reports[2] have been published for balsa and quipo, Sitka spruce, Douglas-fir, mahogany and khaya, sweetgum, and yellow-poplar. All symbols and terminology used in this report conform to the definitions and nomenclature presented in Report No. 1528.[2]

Description of Material

Material for this study was obtained from eight log ends 18 to 32 inches in length, cut from separate yellow birch logs. These were cut into 2-1/2- by 2-1/2-inch sticks, flat-sawn and quarter-sawn planks about 3 inches thick, and 9- by 9-inch blocks, arranged and marked in a manner similar to that used for sweetgum and yellow-poplar.[2] The sticks, planks, and blocks were stored for more than a year in a constant temperature-constant humidity room maintained at 40° F. and 90 percent relative humidity, and were then conditioned for 2 weeks each, in the order given, at 80° F., 97 percent relative humidity; 80° F., 80 percent relative humidity; and 80° F., 65 percent relative humidity.

Preparation of Specimens

It was necessary to discard about two-thirds of the conditioned material because of decay that occurred during the storage period in the 40° F. room. Specimens were prepared only from sound material, and were conditioned to approximately constant weight at 75° F., 64 percent relative humidity after final surfacing and reducing to size.

Because of the losses due to decay, the usual systems employed with previous species[2] for cutting and matching specimens could not be used for the birch specimens, and direct matching was impossible. Furthermore, the limited material reduced the number of specimens below the minimum necessary to form sound conclusions, and made it impossible to obtain a reasonably uniform distribution of specimens over the specific gravity range for the species.

Types of Specimens

Standard 2- by 2- by 8-inch compression prisms, oriented with their long dimensions in the directions of the three principal axes of elastic symmetry, longitudinal, radial, and tangential, were used in tests to determine the Young's moduli and Poisson's ratios. Flat shear plates 1/4 inch in thickness and 6 by 6 or 8 by 8 inches square were used in tests to determine the moduli of rigidity.

Whenever sufficient material was available, moisture sections were cut adjacent to the compression prisms.

Testing Procedure

Instruments and their arrangements, methods of computation, and general testing procedure were as described in Report No. 1528.[2]

For determination of Young's moduli and Poisson's ratios, longitudinal specimens were loaded to approximately 1,250 pounds per square inch; radial and tangential specimens to about 125 pounds per square inch. This was well within the proportional limit of yellow birch, and permitted later use of the specimens for additional tests at other moisture contents.

Two independent sets of values (each from two or more runs at each instrument setting) were made on each specimen at approximately 13 percent moisture content. After testing, the specimens were returned to the 75° F., 64 percent relative humidity room to be reserved for tests at additional moisture conditions.

Moisture sections cut adjacent to the compression prisms at the time of construction were conditioned with the specimen until the time of test in order to provide an estimated specific gravity and moisture content without destroying the specimen.

Explanation of Tables

Table 1 presents a summary, by individual specimens, of the Young's moduli, the ratios E_R/E_L and E_T/E_L, and the six Poisson's ratios. Table 2 presents the moduli of rigidity. The specific gravity and moisture content values are based on data from moisture sections associated with a number of the specimens, and are to be considered as estimates subject to revision when moisture determinations are made on the test specimens.

Discussion of Results

The values for Young's moduli and the Poisson's ratios in table 1, and moduli of rigidity in table 2 represent individual specimens and, therefore, provide information on the range of values experienced in this small series of tests. The number of specimens, however, was insufficient to provide data regarding the effect of specific gravity on the elastic constants, and no information relative to the effect of moisture can be obtained from this study, inasmuch as these tests were made at a single moisture condition. The data for Young's moduli and Poisson's ratios represent several trees, and although the number of specimens was small, can probably be considered as fairly representative of the species. The data for the moduli of rigidity, on the other hand, represent one tree only and must, therefore, be considered as less representative.

Table 1.--Young's moduli and Poisson's ratios of yellow birch at approximately 13 percent moisture content

Log and specimen number	Specific gravity[1]	Moisture content[2]	Young's moduli E_L	Young's moduli E_R	Young's moduli E_T	E_R/E_L	E_T/E_L	Poisson's ratios μ_{LR}	μ_{LT}	μ_{RT}	μ_{RL}	μ_{TR}	μ_{TL}
		Percent	1,000 lb. per sq. in.	1,000 lb. per sq. in.	1,000 lb. per sq. in.								
4-1	0.62	13.8	2,235	172	108	0.077	0.048	0.597	0.394	0.650	0.040	0.393	0.028
4-2	.63	13.6	1,972	165	104	.084	.053	.358	.354	.695	.053	.389	.021
4-3	.65	13.4	1,822	181	87	.099	.048	.269	.417	.665	.063	.539	.018
4-4	.63	13.1	2,205	168	100	.076	.045	.421	.493	.683	.041	.408	.024
4-5	.66	13.0		165						.665	.037		
11-2			1,688					.405	.551				
20-1	.64	12.5			100							.410	.020
29-1	.68	13.4	2,445	181	116	.074	.047	.446	.462	.647	.047	.406	.026
29-2	.65	13.8			107							.406	.024
29-3	.64	12.5			109							.414	.022
30-1	.61	13.2	2,260	156		.069		.495	.553	.695	.040		
46-1	.59	13.5	2,012	123	85	.061	.042	.444	.323	.746	.036	.425	.021
48-1	.66	13.6	1,905	162	128	.085	.067	.390	.406	.743	.035	.468	.034
49-1	.62	13.4	2,202	150		.068		.437	.557	.779	.034		
Average	.64	13.3	2,075	162	104	.078	.050	.426	.451	.697	.043	.426	.024

[1] Specific gravity based on weight and volume when oven dry of moisture sections associated with a number of the specimens.

[2] Moisture content based on values determined from moisture sections associated with a number of the specimens.

Table 2.—Moduli of rigidity of yellow birch at approximately 13 percent moisture content

Specimen number	G_{LR}			G_{LT}			G_{RT} [3]
	Specific gravity [1]	Moisture content [2]	G	Specific gravity [1]	Moisture content [2]	G	
		Percent	1,000 lb. per sq. in.		Percent	1,000 lb. per sq. in.	1,000 lb. per sq. in.
1	0.69	11.1	157	.....	.....	142	34
2	.69	12.8	159	0.63	13.5	130	36
3	.66	12.8	168	.64	13.2	135	33
4	.66	12.7	168	.69	12.4	153	35
5	.66	12.3	177	.65	12.0	150	35
6	.69	12.6	155	.62	10.8	139	34
7	.60	13.5	132	.....	.....	132	37
8	.61	13.3	131	.....	.....	135	36
9	.60	13.4	137	.....	.....	.....	36
Average	.65	12.7	154	.65	12.4	140	35

[1] Specific gravity based on weight and volume when oven dry of moisture sections associated with a number of the specimens.

[2] Moisture content based on values determined from moisture sections associated with a number of the specimens.

[3] Values of specific gravity and moisture content were not determined, but were assumed to be approximately the same as for G_{LR} and G_{LT} specimens since the three groups of specimens were from the same log and were handled and stored similarly.