

# M E C H A N I C A L   P R O P E R T I E S   O F G U A T E M A L A   P I N E   2   B Y   4 ' S

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## ABSTRACT

The current industrial practice in Guatemala is to use the allowable mechanical property values of visually graded U.S. southern pine to design engineered structures because these values are not available for Guatemala pines. Data on graded lumber are important because truss manufacturing plants in Guatemala use significant volumes of pine. Mechanical property values were determined by conducting bending tests on 8-foot- (2.44-m-) long, nominal 2- by 4-inch (38- by 89-mm) pine, primarily *Pinus oocarpa*, from two regions in Guatemala. The lumber was dried to 18 percent moisture content and visually graded using U.S. standards. Results of this study indicate that visually grading lumber using U.S. procedures gives an acceptable separation of property values among grades of *Pinus oocarpa*, and Guatemala pines have greater density, flexural strength, and stiffness than U.S. southern pine. Opportunities exist to reduce the waste of Guatemala pines by increasing the use of visually graded lumber and adopting standards for a systematic derivation of allowable property values.

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**M**ore than 300 species of trees grow in Guatemala. Most of the wood used for structural purposes are softwoods, predominantly pines. Softwood lumber used for structural purposes in Guatemala is both graded and ungraded. When graded, visual grading procedures follow those given in U.S. standards (14). Allowable mechanical property values for Guatemalan pine are not available; therefore, the values for U.S. southern pine are often used for structural design. Mechanical properties, such as modulus of rupture (MOR) and modulus of elasticity (MOE), are available for most Guatemala species (3,9), but data are based on tests of small, clear specimens. Some mechanical property values on full-size specimens are available for Guatemalan species, but these data are based on lumber graded under Mexican grading rules (4). The lack of mechanical property data on full-size Guatemala pine graded under U.S. standards is particularly important because truss manu-

facturing plants in Guatemala use significant volumes of pine. Without specific data on the inherent variability of lumber produced and graded in Guatemala, it is not possible to estimate the reliability of these trusses.

In 1991, a cooperative study was initiated between the University of San Carlos of Guatemala, the USDA Forest Service Forest Products Laboratory, and Iniciativa Forestal para el Desar-

rollo (INFORDE) to determine the mechanical property values of Guatemalan pine graded by U.S. standards (10). The objectives of this paper are to summarize the results of flexural tests conducted on full-size specimens and compare the results with mechanical property values of similar U.S. species.

## MATERIALS AND METHODS

The material for this study was obtained from three sawmills, two located in Guatemala City and one in eastern Guatemala; logs were from two mountainous regions in Guatemala (**Fig. 1**). Several pine species grow in these regions, but the primary species is *Pinus oocarpa*. These sawmills were chosen because they participated actively in a lumber grading program developed by INFORDE. The logs were sawn at local mills to obtain a maximum yield of 8-foot- (2.44-m-) long 2 by 4's. To minimize transportation of off-grade material to the laboratory, the lumber was first graded in the rough, green state. A total of 180 specimens of each grade (No. 1 and Better, No. 2, and No. 3) were obtained at the mill from the available material. These specimens

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were graded according to the standard grading rules of the Southern Pine Inspection Bureau (SPIB) (13).

The lumber was dried by an industrial cooperator to a maximum moisture content (MC) of 18 percent. Approximately half the lumber was kiln-dried, and the remainder was air-dried. After drying, the lumber was dressed to the standard dry size of 1.5 by 3.5 in. (38 by 89 mm). The dressed, dry lumber was graded again according to SPIB'S standard grading rules for southern pine lumber (13) by a quality supervisor from Timber Products, Inc., Conyers, Ga. The lumber was then transported to the University of San Carlos of Guatemala for testing. Prior to testing, lumber dimension, MC, growth rate, and specific

gravity (SG) were determined (ASTM D 4444 and D 2395)(2).

Mechanical property values of the lumber were determined using ASTM D 198 (2). The lumber was tested on edge in third-point loading using a span-to-depth ratio of 17:1. The visually apparent worst defect was placed as close as possible to the center of the test span with the tension edge randomly located with respect to the direction of loading. Deflections were determined at mid-span using a wire strung between two nails that were driven into the wood at the neutral axis over each support. A rule graduated in 0.1 inch (2.54 mm) was used to measure deflection at mid-span. A constant rate of cross-head movement of approximately 2 inches

(50.8 mm) per minute was used to ensure failure in about 10 minutes.

#### RESULTS AND DISCUSSION

A summary of the physical property data for dressed, dry, nominal 2 by 4 Guatemala pine lumber is presented in **Table 1**. Differences in the number of specimens per grade between the green and dry lumber are due to drying degrade and an inability to accurately grade rough lumber. We noted no difference in MC between the kiln-dried and air-dried lumber. The average MC of the lumber at the time of test was 18 percent. When the three lumber grades were combined, wood growth rate was about nine rings per inch and SG was about 0.50, based on oven-dry weight and volume at 18 percent MC. On the basis of oven-dry weight and volume, SG was 0.54. This SG value is about the same as the 0.55 listed for U.S. southern pine in the National Design Specifications (1). However, when compared on the basis of equivalent grade, adjusted to 18 percent MC (2,7), SG would be 0.52 for No. 1 and Better and 0.48 for No. 2 for U.S. southern pine; SG would be 0.54 for No. 1 and Better and 0.50 for No. 2 for Guatemala pine. Results of this study show that the SG of Guatemalan pine is greater than that of U.S. southern pine on the basis of equivalent grades. The variation in SG is typical of that found for species groupings.

The mechanical property values obtained for Guatemalan pine are summarized in **Table 2**. For MOE and MOR, visual grading yielded a sizable separation between property values. All differ-



Figure 1. — Locations (shaded area) of mountainous regions where logs were obtained from Guatemala.

TABLE 1. — Physical property value summary for nominal 2 by 4 Guatemalan pine.

Lumber grade	No. of specimens	Moisture content			Specific gravity <sup>a</sup>			Rings per inch		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
----- (%) -----										
No. 1 & Better	120	18.0	10	26	0.55	0.39	0.71	10	3	30
No. 2	263	17.9	8	26	0.50	0.29	0.83	9	3	29
No. 3	157	18.3	10	25	0.46	0.27	0.78	7	2	26

<sup>a</sup> Oven-dry weight, volume at test moisture content.

TABLE 2. — Mechanical property value summary of 2 by 4 Guatemalan pine at 18 percent moisture content.<sup>a</sup>

Lumber grade	MOE ( $\times 10^6$ lb./in. <sup>2</sup> )		MOR ( $\times 10^3$ lb./in. <sup>2</sup> )		Percentile				
	Mean	SD <sup>b</sup>	Mean	SD	10	25	50	75	90
No. 1 & Better	2.01	0.47	11.06	1.72	8.51	9.74	11.34	12.22	12.93
No. 2	1.71	0.40	8.06	2.18	5.26	6.40	8.18	9.44	11.00
No. 3	1.18	0.33	5.30	2.26	2.86	3.79	4.65	6.86	8.46

<sup>a</sup> 1 lb./in.<sup>2</sup> = 6894 Pa.

<sup>b</sup> SD = standard deviation.

ences between grades are significant at the 0.001 level using the Tukey test (12). As previously noted, only a portion of the lumber currently used in Guatemala engineered structures is graded. The average MOE of the No. 1 and Better lumber was almost 70 percent greater than that of the No. 3 graded lumber, and the average MOR of the No. 1 and Better lumber was slightly more than twice that of the No. 3. These results indicate that visually grading lumber could increase safety, reliability, and efficiency in structural designs. Improvements in design could also encourage efficiency in the utilization of forest resources in Guatemala.

Manufacturing tolerance and quality assurance procedures vary considerably throughout Guatemala and may differ from those used in the United States. The properties determined in this study are not suggested as allowable design values for Guatemala pine used in the United States, nor is it suggested that the property values we derived using U.S. standards are necessarily appropriate for use in Guatemala. As previously noted, however, it is common practice to apply the property values of U.S. southern pine to Guatemala pine species. To compare the results of this study with those of southern pine, the MOR values were adjusted to an MC of 15 percent using the quadratic surface model given by Green and Evans (6,8). This model was chosen because it was used to obtain the MOR values in the southern pine in-grade testing data presented by Green and Evans (5). The MOE was adjusted using the model given in ASTM D 1990; the same model used by Green and Evans (6) to adjust the U.S. southern pine in-grade testing data.

The results reported in our study indicate that the property values of Guatemala pine 2 by 4's are somewhat greater than those of U.S. southern pine (Figs. 2 and 3). The differences are significant at the 0.05 level by the Tukey test (12). Given the slightly higher SG of Guatemala pine compared with equivalent grades of U.S. southern pine, some increase would be expected. Thus, the historical practice of using U.S. southern pine design values for graded Guatemala pine lumber would appear to be acceptable and probably even conservative. Data reported in this study were for one size of nominal 2 by

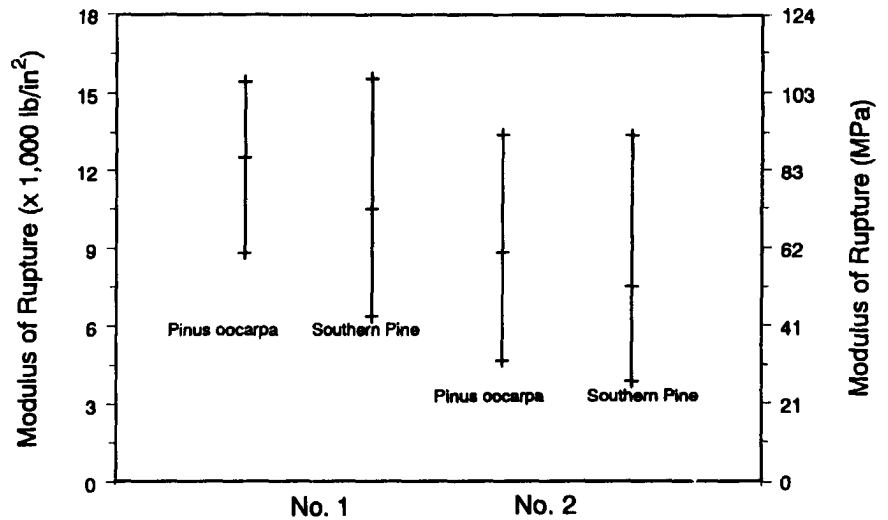


Figure 2. — Comparison of modulus of rupture adjusted to 15 percent moisture content.

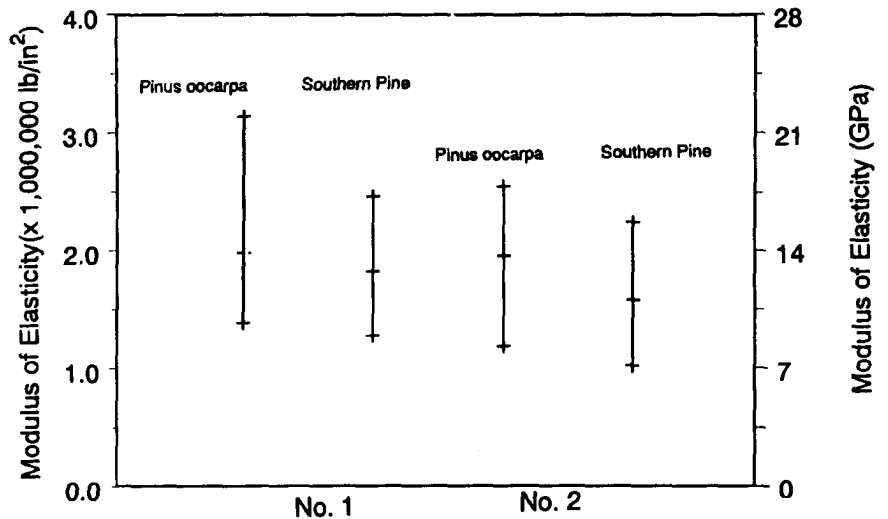


Figure 3. — Comparison of modulus of elasticity adjusted to 15 percent moisture content.

4 lumber in bending, but property values for additional lumber sizes will be available in the Spanish report by Resales and Green (11). When the results of both reports are considered in aggregate, Guatemala engineers may want to consider deriving allowable property values for Guatemala pines using the ASTM D 1990 procedure,

#### CONCLUSIONS

From the results of this study on the mechanical property values of full-size Guatemala pine 2 by 4's, we conclude the following:

- Visual grading by trained personnel under the U.S. grading rules resulted in distinctly different property values for each grade of lumber.
- SG, MOR, and MOE of Guatemalan pine (primarily *Pinus oocarpa*) were slightly greater than that of U. S. southern pine when evaluated for equivalent grades of lumber.
- Visual grading offers significant opportunities for design engineers to improve the safety and efficiency of structural designs.
- Visual grading offers mill operators an opportunity to earn a return on

their investment proportional to the quality of their product.

• Adoption of standards for assigning allowable property values to Guatemalan pine species could encourage efficiency in utilization of wood in structural design, thus helping conserve the forest resource.

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