New Opportunities for Mechanical Grading of Lumber

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Abstract

Traditionally mechanically graded lumber has been produced from 2-inch-thick lumber from softwoods. However, there is increasing interest in using hardwood dimension lumber for structural applications, and procedures have been proposed for the mechanical grading of both softwood and hardwood structural timbers. Research has shown that mechanical grading offers improvements in grading efficiency over visual grading for hardwood dimension lumber and softwood and hardwood structural timbers. Two-inch-thick lumber produced from hardwoods can be mechanically graded using the currently available equipment and procedures that are used to mechanically grade softwoods. It has also been demonstrated that there are no technical barriers to bar the development of standardized mechanical grading procedures for structural timbers. This article discusses extending the mechanical grading process to dimension lumber produced from hardwoods and the possibility of mechanically grading structural timbers of softwoods and hardwoods.

Introduction

Lumber that is mechanically graded has been sorted by a combination of nondestructive evaluation of selected material properties and visual assessment of surface characteristics. The use of two types of sorting criteria allows a producer to make more efficient use of the available timber resource in meeting customer requirements than is possible with visually graded lumber. These criteria also allow a designer more flexibility in meeting design parameters.

Although mechanically graded lumber has been commercially available for more than 30 years, to date it has been produced almost exclusively using nominal 2-inch-thick dimension lumber from softwoods. However, there is increasing interest in using hardwood dimension lumber for structural applications, such as bridges, glued-laminated beams, and trusses (AITC 1985; Janowiak et al. 1995). Procedures have also been proposed for the mechanical grading of structural timbers of both softwoods and hardwoods.

This article discusses extending the mechanical grading process to dimension lumber produced from hardwoods and the possibility of mechanically grading structural timbers of softwoods and hardwoods. The advantages, limitations, and technical justification of applying mechanical grading concepts to these products are stressed.

Mechanical Grading of Hardwood Dimension Lumber

Currently dimension lumber from hardwoods may be visually graded under the *National Grading Rule* in the same way as softwoods (NELMA 1991). Several hardwoods have allowable properties listed in Design *Values for Wood Construction NDS Supplement* (AF&PA 1991) (Table 1). Unlike softwoods-most of which have properties derived from tests of full-sized members under *ASTM D1990 Standard Methods for Determination of Allowable Properties from Tests of Full-Sized Dimemion Lumber* — the properties of hardwoods are derived from tests using small, clear specimens as per *ASTM D245 Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber* (ASTM 1996). It is often difficult to visually identify individual hardwood species after logs have been processed into lumber. Therefore, the allowable properties for most hardwoods are determined as part of a species grouping, with the properties of the group controlled by the weakest species in the group (Table 2).

Thus, if you are a producer of hardwood structural lumber with very little of the controlling species in your species mix, the allowable properties assigned to lumber produced at your mill may be quite conservative relative to the potential of the available resource. Testing of full-sized members and derivation of properties following procedures of *ASTM D1990* might improve property assignment somewhat. However, the inability to identify many individual species would still limit property assignment and lead to inefficient utilization (Green et al. 1994). Research has shown that many of the relationships between strength properties that are used to assign allowable properties to softwoods are similar to those of hardwoods (Figs. 1 and 2) (Green et al. 1994, 1996). Thus, there appears to be no technical reason why hardwood dimension lumber could not be graded using the same procedures and equipment that are used to mechanically grade softwoods.

In 1993, the concept of mechanically grading hardwoods was put to the test. With the cooperation of Northeastern Lumber Manufacturers' Association (NELMA), the Southern Pine Inspection Bureau (SPIB), and the Forest Products Laboratory, 803 pieces of mixed oak nominal 2 by 8s were graded to meet the machine stress-rated (MSR) lumber requirements of 1650f-1.4E. The procedures followed were those of SPIB (Green et al. 1994). The results of this certification showed that although only 1 percent of the lumber qualified as Select Structural by visual grading, 36 percent of it could be assigned properties equal to or greater than those of Select Structural by mechanical grading (Table 3). If the lumber had been graded with characteristics such as checks, shake, splits, wane, and warp limited to those of No. 3 visually graded lumber rather than those of No. 2, 95 percent of it would have made 1650f-1.4E. An unpublished study with 900 mixed maple nominal 2 by 6s indicated that most of the lumber would make MSR 2100f-1.8E, a value greater than the 1300f-1.3E for Select Struc-

Table 1.—Hardwood species combinations (AF&PA 1991).

Species or combination	Species that may be included
Aspen	Big tooth aspen
Beech-Birch-Hickory	American beech
	Bitternut hickory
	Mockernut hickory
	Nutmeg hickory
	Pecan hickory
	Pignut hickory
	Shagbark hickory
	Water hickory
	Sweet birch
Cottonwood	Eastern cottonwood
Mixed Maple	Black maple
	Red maple
	Silver maple
	Sugar maple
Mixed Oak	All species included in "Red Oak" and "White Oak" groupings
Northern Red Oak	Black Oak
	Northern red oak
	Pin oak
	Scarlet oak
Red Maple	Red maple (not available)
Red Oak	Northern Red Oak grouping, plus
	Cherrybark oak
	Laurel oak
	Southern red oak
	Water oak
	Willow oak
White Oak	Bur oak
	Chestnut oak
	Live oak
	Overcup oak
	Post oak
	Swamp chestnut oak
	Swamp white oak
	White oak

Table 2.—Mean property values for green, clear wood from *ASTM D245* (ASTM 1996).

Grouping	Species	MOE ($\times 10^6$ lb./in.^{2})	MOR (lb./in.^{2})
Red Oak	Black oak	1.182	8,820
	Cherrybark oak	1.790	10,850
	Laurel oak	1.393	7,940
	Northern red oak	1.353	8,300
	Pin oak	1.318	8,330
	Scarlet oak	1.476	10,420
	Southern red oak	1.141[a]	6,920[a]
	Water oak	1.552	8,910
	Willow oak	1.286	7,400
Mixed Maple	Black maple	1.328	7,920
	Red maple	1.386	7,690
	Silver maple	0.943[a]	5,820[a]
	Sugar maple	1.546	9,420

[a] Controls allowable properties of the group.

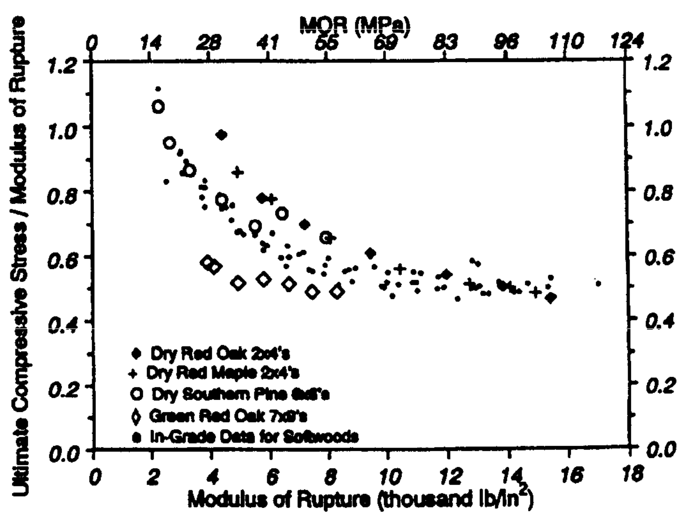

Figure 1.—Relationship between compression strength parallel-to-grain and bending strength for hardwood MSR lumber and mechanically graded timbers (Green et al. 1996).

tural mixed maple. These two examples illustrate the potential of mechanical grading to more efficiently use the hardwood resource.

Currently the only real limitations to mechanically grading 2-inch-thick hardwood dimension lumber are those related to supply and demand. Although hardwood MSR lumber is not currently available in the marketplace, all the technical justifications and procedures are in place. For an agency certified to mechanically grade softwood structural lumber, approval to grade hardwoods should not be a limitation. However, property assignment procedures for allowable compression strength parallel-to-grain might have to be modified for some hardwoods, such as gum, sycamore, and tupelo, that commonly have interlocked grain (Green et al. 1994; Green and Resales 1996).

Mechanical Grading of Structural Timbers

Timbers are defined in *ASTM D9 Standard Terminology Relating to Wood* as "lumber 5 or more inches in least dimension" (ASTM 1996). In general usage however, 4-inch-thick lumber is sometimes classified as a "timber." Structural timbers are used in a variety of engineered applications, such as railroad bridges and timber-frame structures for commercial and industrial applications. Unlike 2-inch-thick dimension lumber, both softwoods and hardwoods are used extensively as structural timbers.

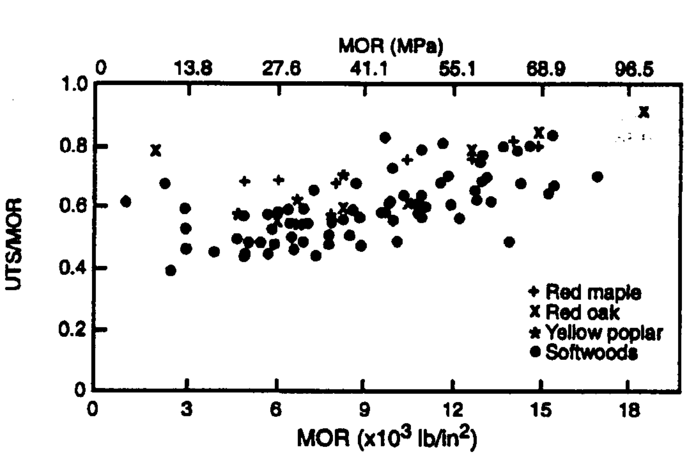

Figure 2.—Relationship between tensile strength parallel-to-grain and bending strength for hardwood MSR lumber (Green et al. 1994).

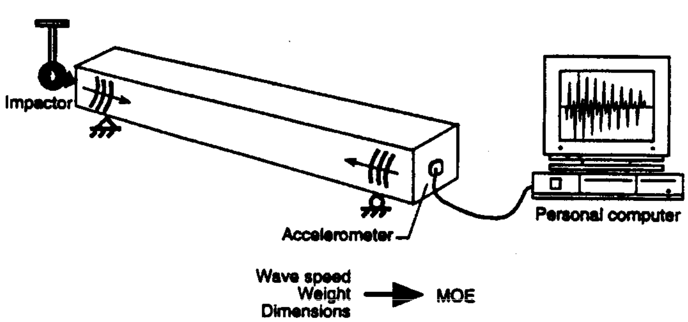

Figure 3.—Experimental determination of MOE using longitudinal stress waves.

The grading of structural timbers is based on visual assessment of growth characteristics and defects, with properties derived from tests of small, clear specimens under *ASTM D245* (ASTM 1996). Unlike dimension lumber, descriptions for timbers having a similar grade name are not standardized across species or among agencies. Standardized procedures for mechanical grading of structural timbers are not currently available. Thus, the advantages of mechanically graded lumber available for dimension lumber are not available either to the producer or the user of structural timbers. There is a growing interest in establishing mechanical grading procedures for virgin timbers (Green et al. 1996) and opportunities to use mechanical grading to more accurately characterize the properties of recycled timbers (Falk et al. 1995). Recent research has provided the technical basis for the mechanical grading of structural timbers and demonstrated its application in grading mixed oak 7 by 9 timbers.

The traditional approach to producing mechanically graded lumber relies on the relationship between modulus of rupture (MOR) and modulus of elasticity (MOE) in the edgewise orientation for assignment of allowable properties. The standard machine grading method sorts the lumber using bending stiffness in the flatwise orientation to predict edgewise MOE.

An approach perhaps more easily adapted to sorting structural timbers uses longitudinal stress wave techniques to estimate edgewise MOE. With this method, puke energy is introduced to the specimen and echo waves are recorded to obtain a time between stress wave peaks (Fig. 3). The stress wave MOE obtained from this information is well correlated with static edgewise MOE (Green and Kretschmann; Kretschmann and Green [both in press]). That there is a significant correlation between static MOE and MOR for timbers is of little doubt.

Table 3.—Results of MSR certification for oak 2 by 8s (Green et al. 1994).

Grade	Yield	Allowable property: Bending strength	Allowable property: MOE
	(%)	(lb./in.^{2})	($\times 10^6$ lb./in.)
Visual			
Select Structural	1	1,350	1.4
No. 1	3	990	1.3
No. 2	33	960	1.2
No. 3	63	540	1.1
MSR			
1650f-1.4E	36	1,650	1.4
If No. 3 Visual	95	1,650	1.4

Research has shown that the relationship between ultimate compression stress parallel-to-grain (UCS) and MOR of dry Southern Pine timbers is similar to that of dry softwood and hardwood dimension lumber (Fig. 1). The UCS-MOR relationship for green, mixed oak timbers is approximately constant. The flattening of this relationship relative to that for dry lumber is similar to that predicted for green dimension lumber of softwoods (Green and Krecschmann 1991). Although tensile tests were not conducted on timbers, the property relationships between MOR and MOE and UCS and MOR seem to follow trends expected for dimension lumber. Thus, there is no reason to doubt that the ratio between tensile and bending strength in current ASTM standards — *ASTM D245* and *ASTM D1990* — could be applied to structural timbers. Allowable properties for shear and compression perpendicular-to-grain are already available for virtually all species in *ASTM D245*.

The potential of a mechanical grading system to accurately identify material with superior properties was demonstrated with mixed oak 7 by 9 timbers (Kretschmann and Green [in press]). Research data established a lower confidence bound on the MOE-MOR relationship (Fig. 4). This confidence bound was used to set boundaries for MOE for two MSR grades: 1500f-1.5E and 1900f-1.7E. Visual characteristics, such as checks, shake, splits, wane, and warp, were set equivalent to those of No. 2 visually graded timbers. A second set of specimens was then randomly selected for each grade and tested to destruction to verify the assigned properties. It was estimated that 93 percent of the mill run timbers could meet the 1.5E criteria, and that 70 percent would meet the 1.7E criteria.

Practical concerns for applying mechanical grading concepts to structural timbers still need to be addressed. These include details relating to use of the system at an individual mill site and details of a quality assurance program. However, it has been demonstrated that the technical barriers have been addressed and that mechanically graded timbers can be reliably graded in an efficient manner.

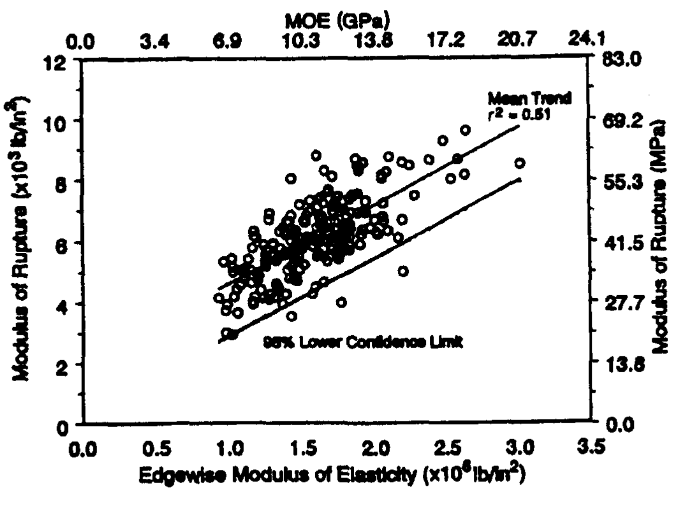

Figure 4.—Relationship of bending strength to bending stiffness for mixed oak 7 by 9 timbers (Green et al. 1996).

Summary

Research has shown that mechanical grading offers improvements in grading efficiency over visual grading for hardwood dimension lumber and hardwood and softwood structural timbers. Two-inch-thick lumber produced from hardwoods can be mechanically graded using the currently available equipment and procedures that are used to mechanically grade softwoods. It has also been demonstrated that there are no technical barriers to bar the development of standardized mechanical grading procedures for structural timbers of softwoods and hardwoods.

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