Overview

The Northeastern Forest Alliance (NEFA) was created in August, 1986 by the Natural Resources Commissioners from Maine, New Hampshire, New York and Vermont. The four-state Alliance has as one major goal to promote the Northeast forest and its products on a regional basis. One objective of this goal is to promote fuller use of hardwood species that are currently being harvested but are vastly underutilized.

Today there are thousands of businesses and industries related to wood products in the NEFA region. Each of these companies relies upon the abundant supply of hardwood and softwood resources found in the more than 40 million acres of commercial quality timber in the NEFA region.

While local primary and secondary wood processors currently enjoy good supplies, the world market and worldwide demand for both raw wood and wood products continues to grow at an unprecedented rate. Even policy changes within the U.S. are causing major shifts in demand from the west coast to the northeast, and are increasing demands and therefore prices on woods traditionally favored for various products and uses. These new demands are forcing different approaches to better wood utilization and at the same time are creating substantial new opportunities for better utilization of formerly unused or underutilized wood species and grades.

RED MAPLE

In the NEFA region, red maple (*Acer Rubrum*), is an abundant species that due to tradition, abundance of other preferred species, and a lack of market interest, has been harvested, but has not been fully utilized. Because of these factors, the qualities and characteristics of red maple have not been well documented, nor have its properties and availability been widely publicized.

NEFA has undertaken the study of red maple to more fully document its characteristics. This Compendium is the aggregation of those studies and is intended for wide dissemination and use by landowners, mill owners, primary and secondary wood processors, architects, designers, highway departments and other wood users.

This Compendium contains:

- Overview – completed in early 1994
- Whitewood Study – completed in 1993
- Strength/Stress Study – completed in 1993
- Treatability Study – to be completed in early 1994
- Fasteners – completed in early 1994
- Practical Applications – to be completed
- Literature Search – to be completed in 1994
- Bibliography – to be completed in 1994

QUALITIES OF RED MAPLE

The wood of all the so-called soft maples (red maple and silver maple) is similar, and although it is 25% softer than hard maple, it is suited to most of the same uses and possesses the same finishing properties. Soft maple is well suited for enamel finishes and brown tones.

Soft maple can be used for lumber, paneling, furniture and cabinets. It is available as lumber and veneer, and it falls in the "average" price range.

It machines well, has fair resistance to splitting in nailing, and good resistance to splitting in screwing. It is well-suited for gluing.

AVAILABILITY

In 1992, the USDA Forest Service published a technical report showing cubic-foot volumes and board foot volumes for major timber species in the United States. The report included maps showing the distribution of growing stock and sawtimber volumes of 26 species, including "soft maple" (red maple and silver maple). The data upon which the maps were based came from the forest inventories of the individual states, and represented forest conditions at the time of the most recent inventory – between 1972 and 1989.

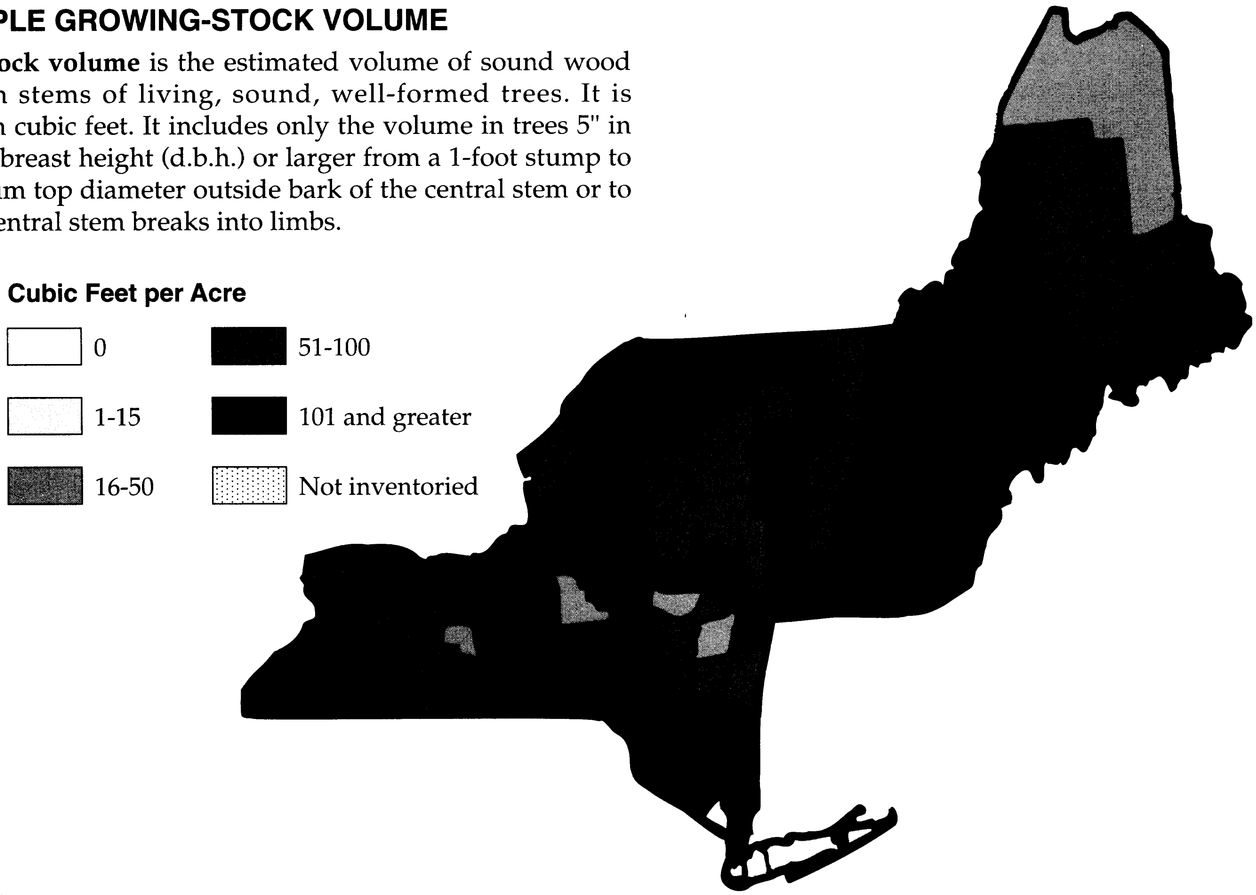
The key units of measure were cubic feet for growing stock, and board feet for sawtimber because these units are meaningful to timber growers, sellers, and buyers. Although this information was previously presented in tables, technology now available through geographic information systems (GIS) now allowed this information to be presented in easy-to-read maps.

Timberland is defined as land at least 16.7 percent stocked by forest trees of any size, or formerly having had such tree cover, not currently developed for non-forest use, capable of producing 20 cubic feet of industrial wood per acre per year, and not withdrawn from timber utilization by legislative action, conservation easements, or other restrictions.

For each county, volumes per acre were determined by taking the average volume per acre of a species or species group found on survey plots and dividing it by the total timberland acreage in the county. The maps are intended to show species occurrence and volume distributions in a general way.

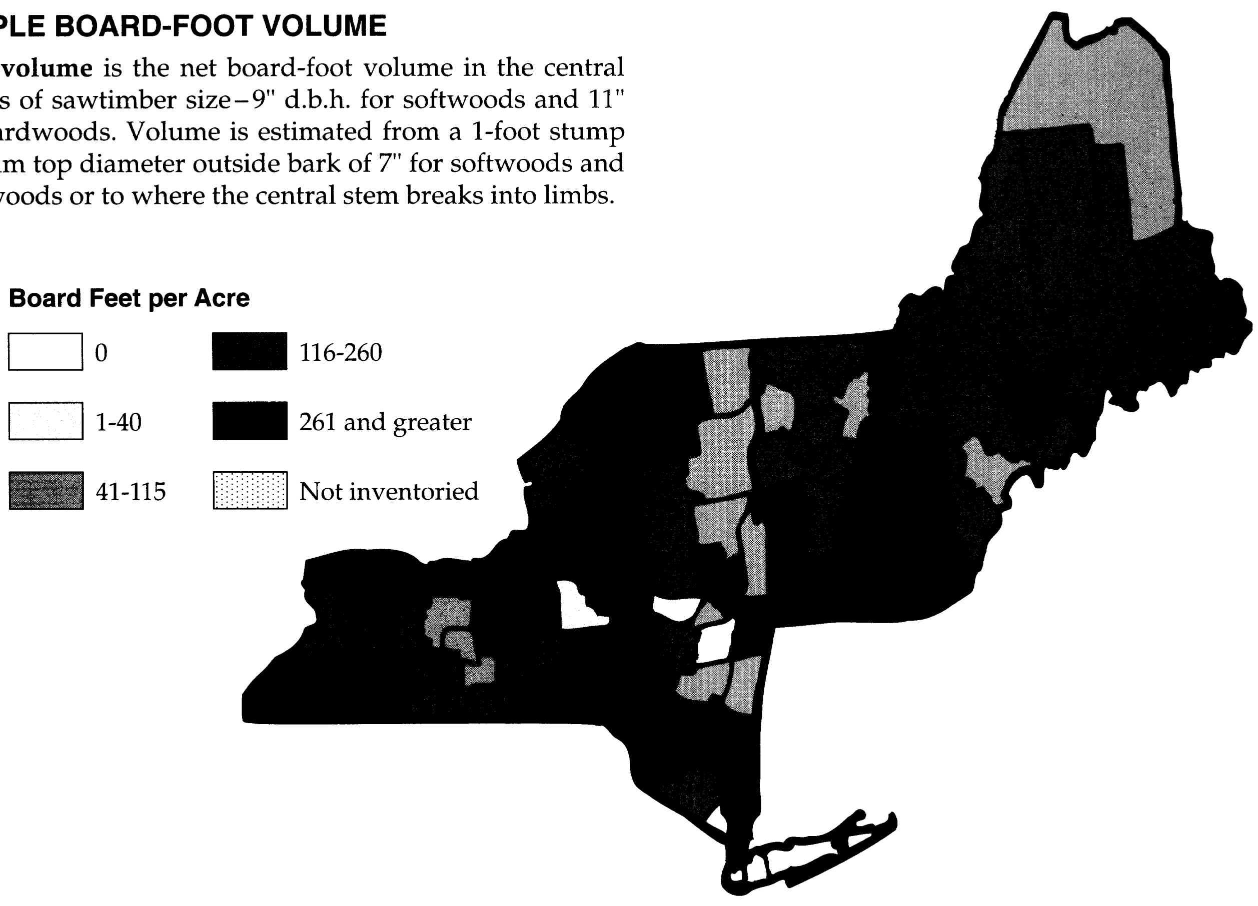
SOFT MAPLE GROWING-STOCK VOLUME

Growing-stock volume is the estimated volume of sound wood in the main stems of living, sound, well-formed trees. It is expressed in cubic feet. It includes only the volume in trees 5" in diameter at breast height (d.b.h.) or larger from a 1-foot stump to a 4" minimum top diameter outside bark of the central stem or to where the central stem breaks into limbs.



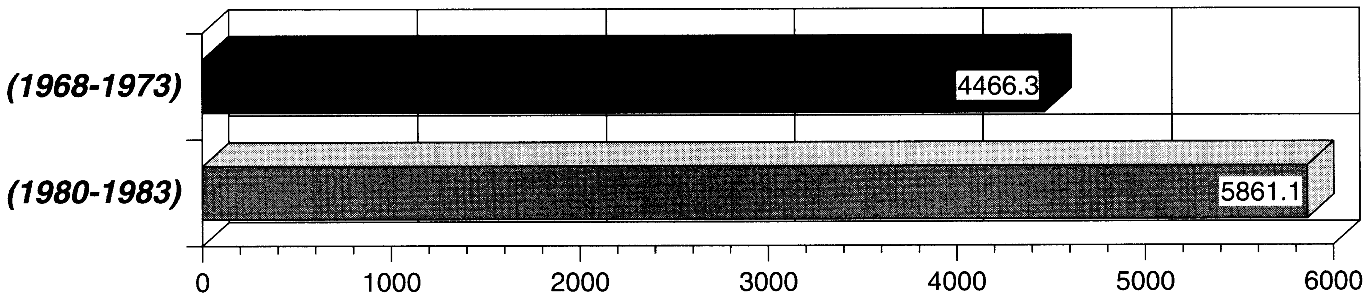
SOFT MAPLE BOARD-FOOT VOLUME

Sawtimber volume is the net board-foot volume in the central stem of trees of sawtimber size–9" d.b.h. for softwoods and 11" d.b.h. for hardwoods. Volume is estimated from a 1-foot stump to a minimum top diameter outside bark of 7" for softwoods and 9" for hardwoods or to where the central stem breaks into limbs.



INCREASES IN GROWING STOCK VOLUME OF RED MAPLE IN NEFA REGION

(in Millions of Cubic Ft. over approximately 10 years)

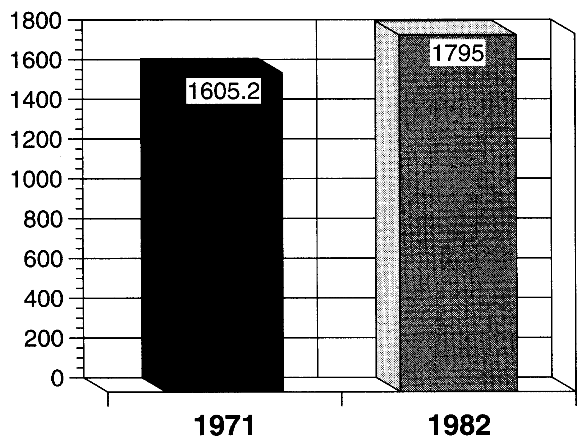


Overall Increase = 1,394.8 million cubic ft. or 31.2%+

INCREASES IN GROWING STOCK VOLUME OF RED MAPLE BY STATE

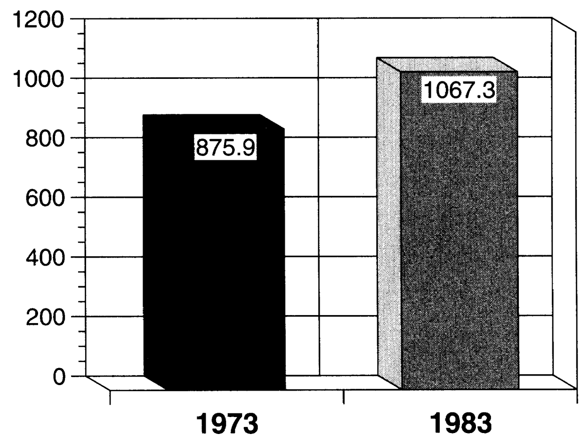
(in Millions of Cubic Ft. over approximately 10 years)

MAINE



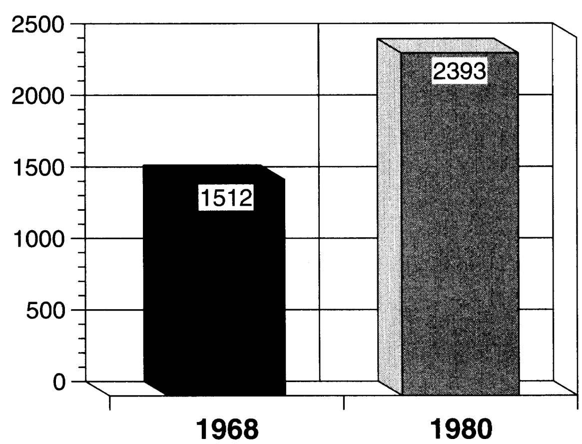
Increase = 189.8 million cu. ft. or 12%+

NEW HAMPSHIRE



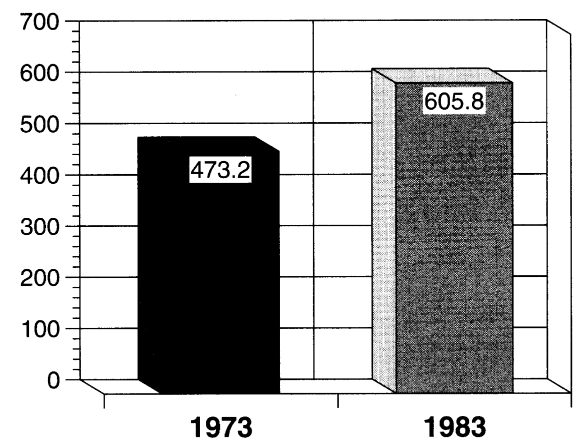
Increase = 191.4 million cu. ft. or 22%+

NEW YORK



Increase = 881 million cu. ft. or 58%+

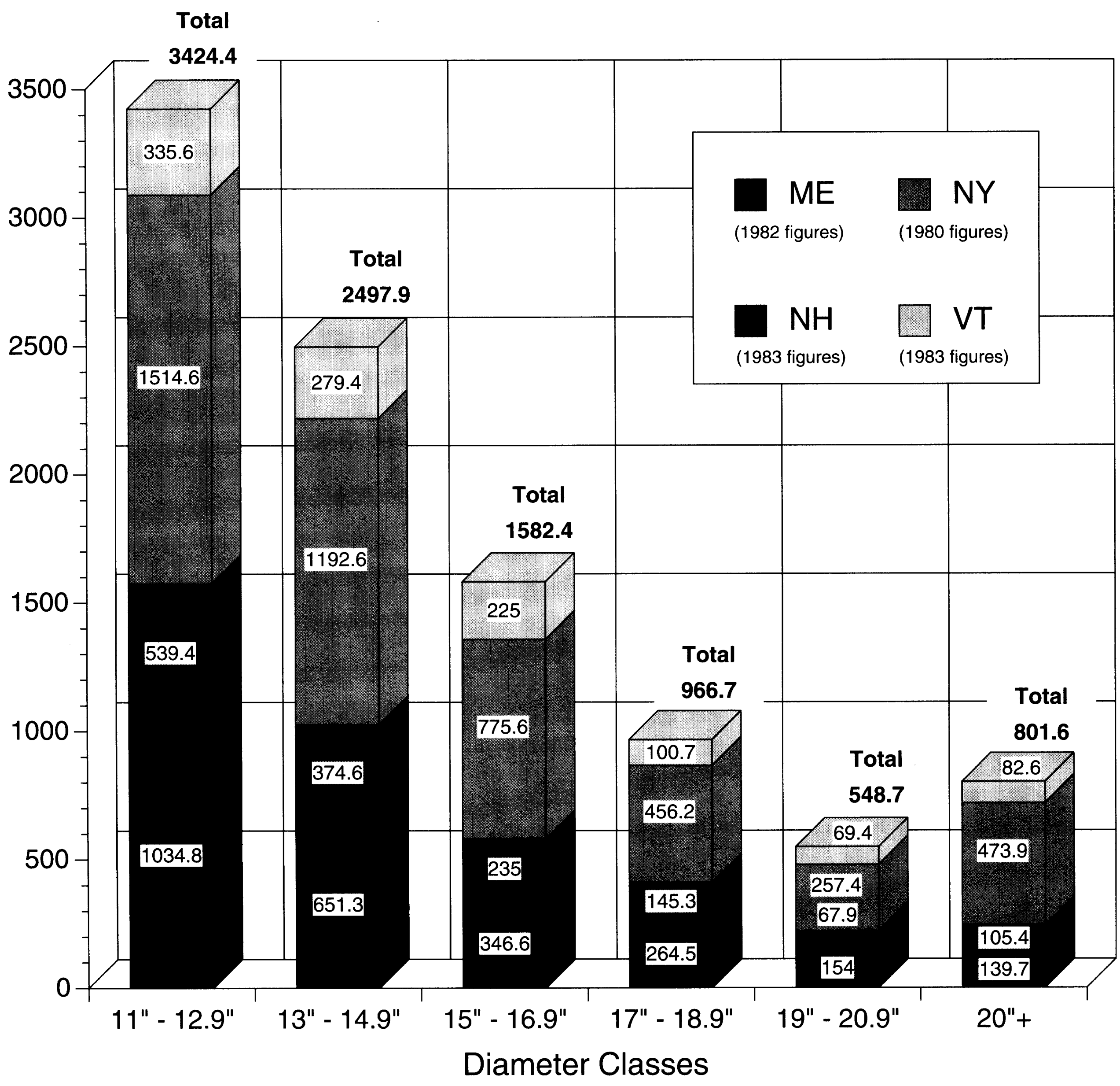
VERMONT



Increase = 132.6 million cu. ft. or 28%+

NET BOARD FT. VOLUME OF RED MAPLE SAWTIMBER IN NEFA REGION BY DIAMETER CLASS

(in Millions of Board Feet)



GRAND TOTAL = 9,821.7 million board in sawtimber size classes.

Above information from USDA Resource Bulletins Nos.: NE-81, NE-71, NE-88, NE-87.

FOR MORE INFORMATION

The USDA Forest Service Agricultural Handbook 654, "Silvics of North America, Volume 2, Hardwoods, pages 60-69 offers further information about the characteristics of red maple.

Red Maple Whitewood Study

BACKGROUND

As part of the Northeastern Forest Alliance's initiative to expand markets and develop new products or uses for presently underutilized and abundant hardwoods like red maple, a formal study was undertaken in 1991 and 1992 to determine the properties of red maple. The first component was to study "Whitewood" yields. This study, funded by NEFA, was coordinated by Dave Stevens and Jack Dwyer of the Marketing Utilization and Development Division of the Vermont Department of Forests, Parks, and Recreation. Information from this study is now being distributed to primary and secondary wood manufacturers, as well as wood users.

WHY THE WHITEWOOD STUDY?

When Red Maple logs are processed into lumber for furniture manufacturing, the boards may be graded and sorted according to the amount of "whitewood" they contain. "Whitewood" is a term given to the lighter colored wood sawn from the outer part of the log. "Whitewood" is more valuable for its use in products such as furniture than is the inner dark colored part of the log (generally referred to as heartwood).

This value difference is determined by market demand and customer preference, and has little to do with the physical characteristics of the wood. For someone sawing Red Maple into lumber, or a manufacturer purchasing lumber, knowing how much whitewood lumber, and in what grades, can be produced from a given run of logs, is important information, particularly when considering the use of alternative species.

RESULTS

The study was conducted with a sample of 310 Red Maple logs. These logs were "woods run" and were harvested in central Vermont. The logs were graded by Jack Dwyer and yielded the following:

USFS LOG GRADES*

	Grade 1	Grade 2	Grade 3	Total
No. of Logs	86	126	98	310
Diameter/ Range	13-22"	10-19"	10-16"	
Volume (Int. 1/4)	8,952	8,618	4,574	22,144

* For more information on USFS Log Grades, see the USDA Forest Service Technical Report NE-1, 1973.

The logs were sawn into lumber at the Plumb Lumber Co. in Andover, VT. The boards were then graded based on NHLA Standard Grades. This grading system grades lumber using primarily on size, type and spacing of physical defects found in the boards.

GRADE YIELD OF LUMBER BASED ON **NHLA STANDARD GRADES

USFS LOG GRADES

Lumber Grades	Grade 1	Grade 2	Grade 3	All (Comb)
FAS	17.0%	10.8%	1.7%	11.4%
Select	25.1%	19.3%	5.6%	18.8%
1 Common	16.2%	17.4%	11.8%	15.8%
2 Common	9.4%	13.2%	17.5%	12.6%
3 Common	32.3%	39.3%	63.3%	41.5%

** For NHLA (National Hardwood Lumber Association) grades, see NHLA Grading Handbook.

The boards were then regraded using the NHLA "white" lumber grades for Red Maple. This grading system adds the factor of color to the physical defects used in the NHLA Standard Grades. NHLA "White Lumber Grades" would be used primarily by furniture manufacturers. Whitewood grading was supervised by Sarah Smith, a Forest Product Utilization Specialist with the University of New Hampshire Cooperative Extension Service.

GRADE YIELD OF LUMBER BASED ON NHLA WHITE LUMBER GRADES

Lumber Grades	Grade 1	Grade 2	Grade 3	All (Comb)
FAS	15.7%	10.9%	2.4%	11.1%
Select	23.7%	18.6%	4.9%	17.8%
1 Common	10.1%	12.3%	9.2%	10.8%
2 Common	9.5%	12.6%	15.3%	11.9%
3 Common	41.0%	45.7%	68.1%	48.4%

(over →)

DIFFERENCES WHEN GOING FROM NHLA GRADE YIELD TO NHLA WHITE LUMBER GRADE YIELD

Lumber Grades	Grade 1	Grade 2	Grade 3	All (Comb)
FAS	-1.3%	+0.1%	+0.7%	-0.3%
Select	-1.4%	-0.7%	-0.7%	-1.0%
1 Common	-6.1%	-5.1%	-2.6%	-5.0%
2 Common	+0.1%	-0.6%	-2.2%	-0.7%
3 Common	+8.7%	+6.4%	+4.8%	+6.9%

As the above figures indicate, applying the NHLA White Lumber Grade Yield Standards has very little effect on the FAS, Select, and 2 Common categories. The effects are most significant in the 1 Common category where yield is reduced by about 30%. This volume is shifted primarily to the 3 Common category where volume increases by about 16%.

The project leaders want to acknowledge the special effort Plumb Lumber put into this study. Their contribution is greatly appreciated.

Preservative Treatment of Red Maple

INTRODUCTION:

The states of New York and Pennsylvania, along with the entire Northeast, import considerable volumes of preservatively treated southern yellow pine and Douglas-fir for structures such as decks, bridges, fences, docks, poles, and so on. Research has already shown that a number of locally available eastern hardwoods are suitable for structural purposes along these lines. Long-term utilization of under-utilized eastern hardwoods, such as red maple, for exterior structural purposes, and new market development for these products is highly dependent on the ability to protect them with wood preservatives. Currently, creosote and pentachlorophenol are the only two treatment chemicals with a widely accepted and proven record of effectiveness. Copper naphthenate, an historically effective preservative compound with the added benefit of having low environmental restriction, was investigated for its ability to treat red maple and for its biological effectiveness.

ABSTRACT:

This project investigated the treatability of red maple sapwood and heartwood with water, toluene, CCA, ACQ, creosote, and water and toluene borne copper naphthenate. Also, agar block decay tests were performed with CCA, and water and toluene borne copper naphthenate solutions with brown rot (*Postia placenta*), white rot (*Trametes versicolor*), and soft rot (*Chaetomium globosum*) fungi.

Substantial differences were found between heartwood and sapwood treatability. Full-cell impregnation resulted in sapwood samples being consistently treated to retentions of 30-40 pcf, while the heartwood was only about 5-15 pcf. Preservative penetration into heartwood was poor; only about 3 mm transverse and 15 mm longitudinally. This may indicate that incising of heartwood faces will be needed for good performance.

CCA protected against brown and white rot fungi at low retentions, 0.1% Cu weight/weight. Similar to past work, however, higher retention loadings were needed for soft rot protection. On an equivalent copper loading basis the oil-borne copper naphthenate was more effective than the water-borne formulation against white and soft rot fungi.

PURPOSE OF STUDY:

The goals of this project were to determine the treatability of red maple heartwood and sapwood and to determine the effectiveness of copper naphthenate wood preservative for the treating of red maple sapwood.

STUDY PLAN:

Literature Survey

A survey of past research studies and reports on the treatability of red maple, and the types of preservatives that have been used to treat red maple will be conducted and summarized in a written report. Additionally, publicly available information on the toxicity of copper naphthenate will be collected, mostly by Dr. R.C. DeGroot at the Forest Products Laboratory, and forwarded.

Treatability of Red Maple

Freshly cut red maple sawlogs were obtained and sawn into 5/4" boards in the Wood Products Engineering sawmill. Specific efforts were made during sawing to secure all heartwood and all sapwood boards. After kiln drying to below 10% mc the boards were planed and ripped into 1" by 1" square strips. From each strip at least eight 6" long end-matched specimens were prepared for subsequent preservative pressure treating.

Treatability of red maple sapwood and heartwood, as determined by retention and penetration, was determined with several different wood preservative compounds. The active ingredients of respective treating solutions are intended to be of such strength that will produce a retention that is comparable in performance to a retention of 0.6 pcf CCA.

Preservatives

Oil-Borne:		
		Creosote
		Cu Naphthenate (1% Cu in toluene)
Water-Borne:		
	Acidic	CCA-C (1%)
	Alkaline	ACQ (1%)
		Cu Naphthenate (1% Cu)

Control Solutions

Water
Toluene

Treatment took place via the full-cell process; 15 minutes vacuum (28" Hg) followed by 30 minutes pressure (100 psi). There were 15 specimen replicates for each treating group.

Effectiveness of Copper Naphthenate Wood Preservative for the Treating of Red Maple:

Using the American Wood-Preservers' Association Standards as a guide, sapwood specimens of red maple were treated with several wood preservatives, at several retention levels, and were then exposed to three different types of wood decay fungi, as follows:

Test Specimens:

Red Maple sapwood (5 x 10 x 20 mm)

Preservatives:

Copper naphthenate (water-borne)

Copper naphthenate (oil-borne)

Chromated copper arsenate (CCA)

Treating Solution:

2.0	% weight/weight	Cu metal
1.5	"	"
1.0	"	"
0.25	"	"
0.125	"	"

Full-Cell Treatment:

30 minute vacuum

30 minute atmospheric pressure

Fixation:

6 days at ambient lab temperature

1 day at 60°C

Exposure Time:

12 weeks

Decay Test:

Agar Block Test

2% MEA (malt extract agar) for brown and white rot

2% Agar and 2x Abrams nutrient for soft rot decay chambers

16 oz. French square bottle decay chambers

50 ml culture media per decay chamber

Fungi:

Postia placenta (brown rot)

Trametes versicolor (white rot)

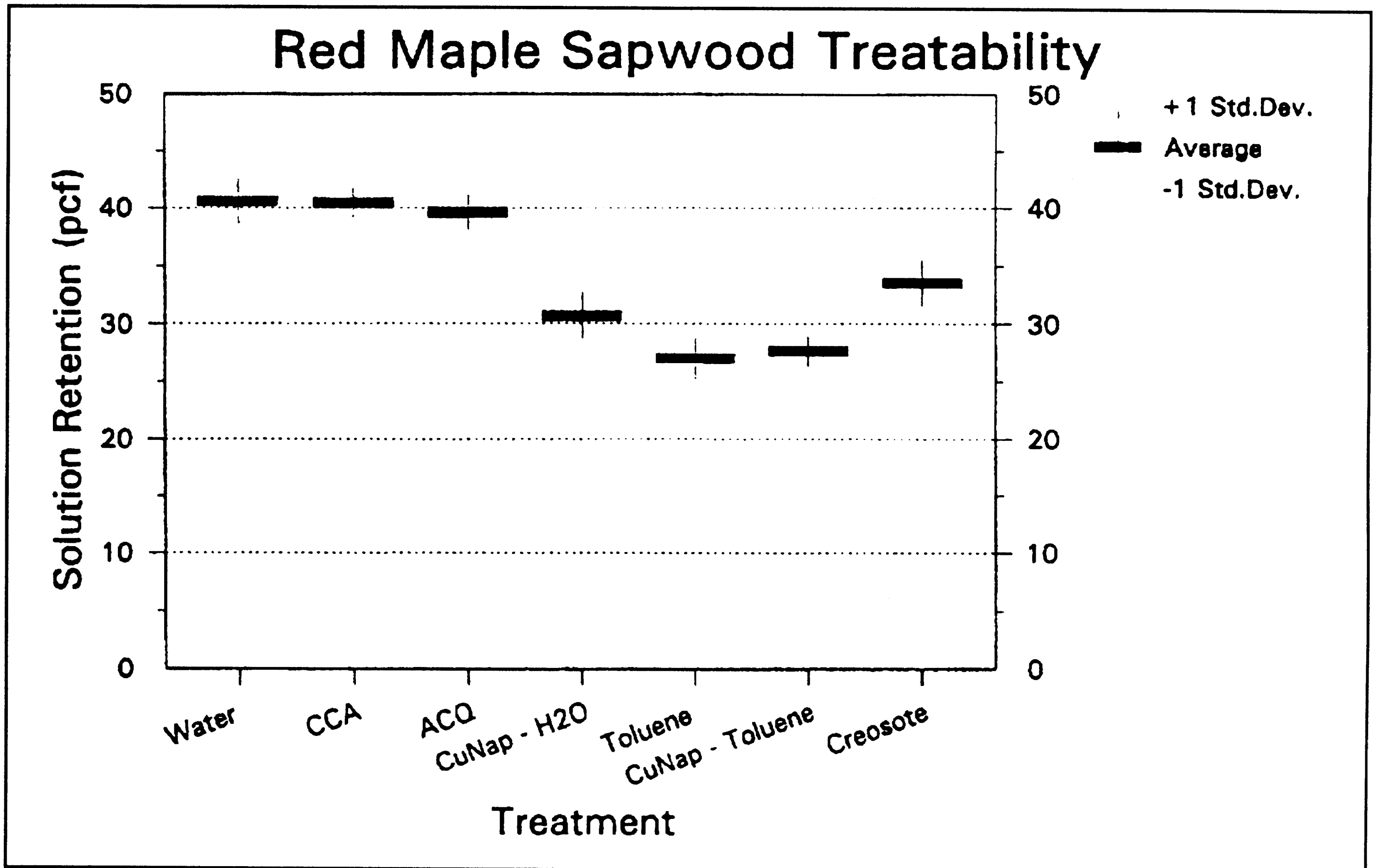
Chaetomium globossum (soft rot)

This report was conducted by:

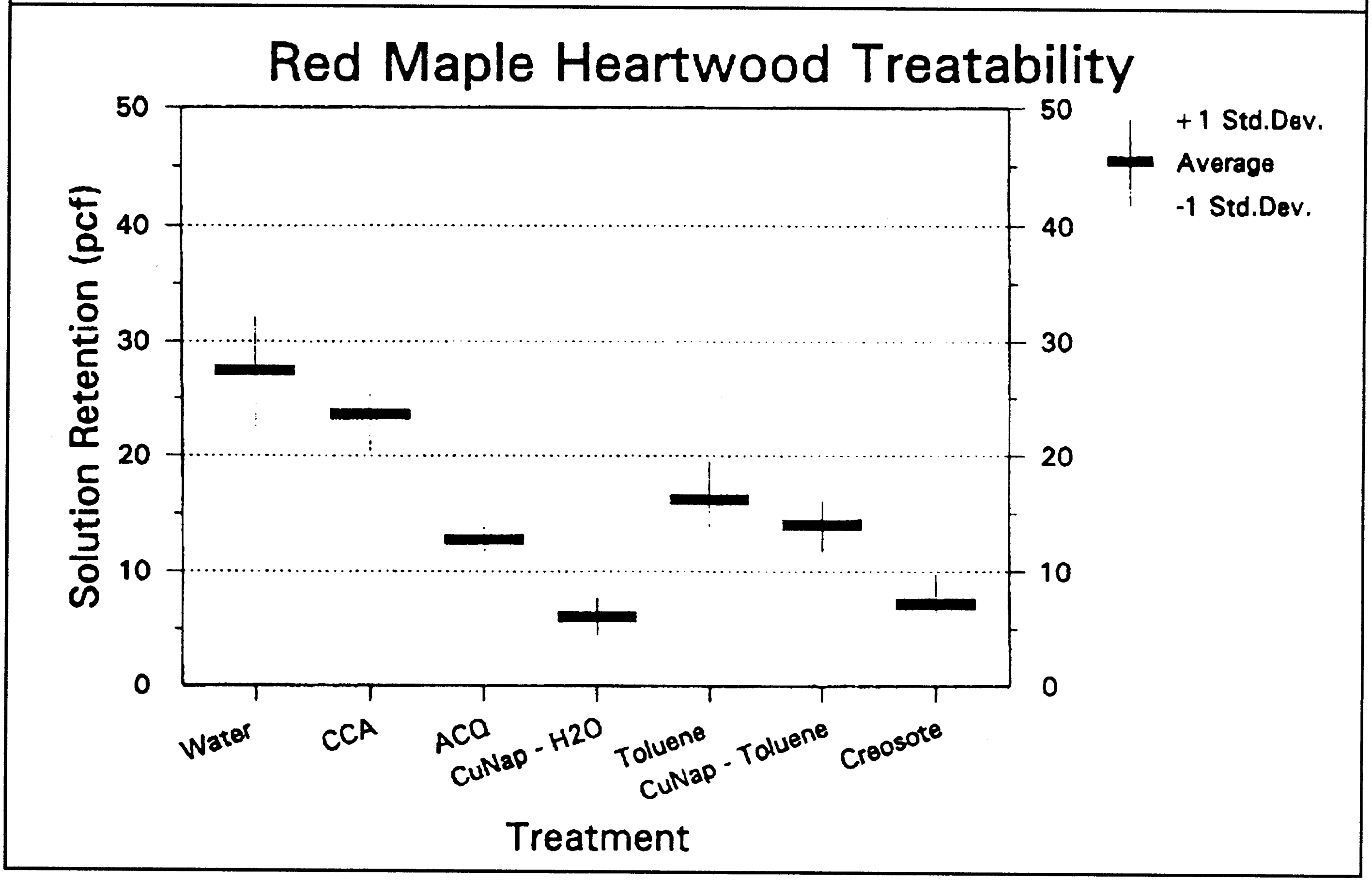
William B. Smith, Associate Professor of Wood Products Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY.

Nazri Abdullah and Douglas Herdman, Graduate students, Wood Products Engineering, SUNY College of Environmental Science and Forestry.

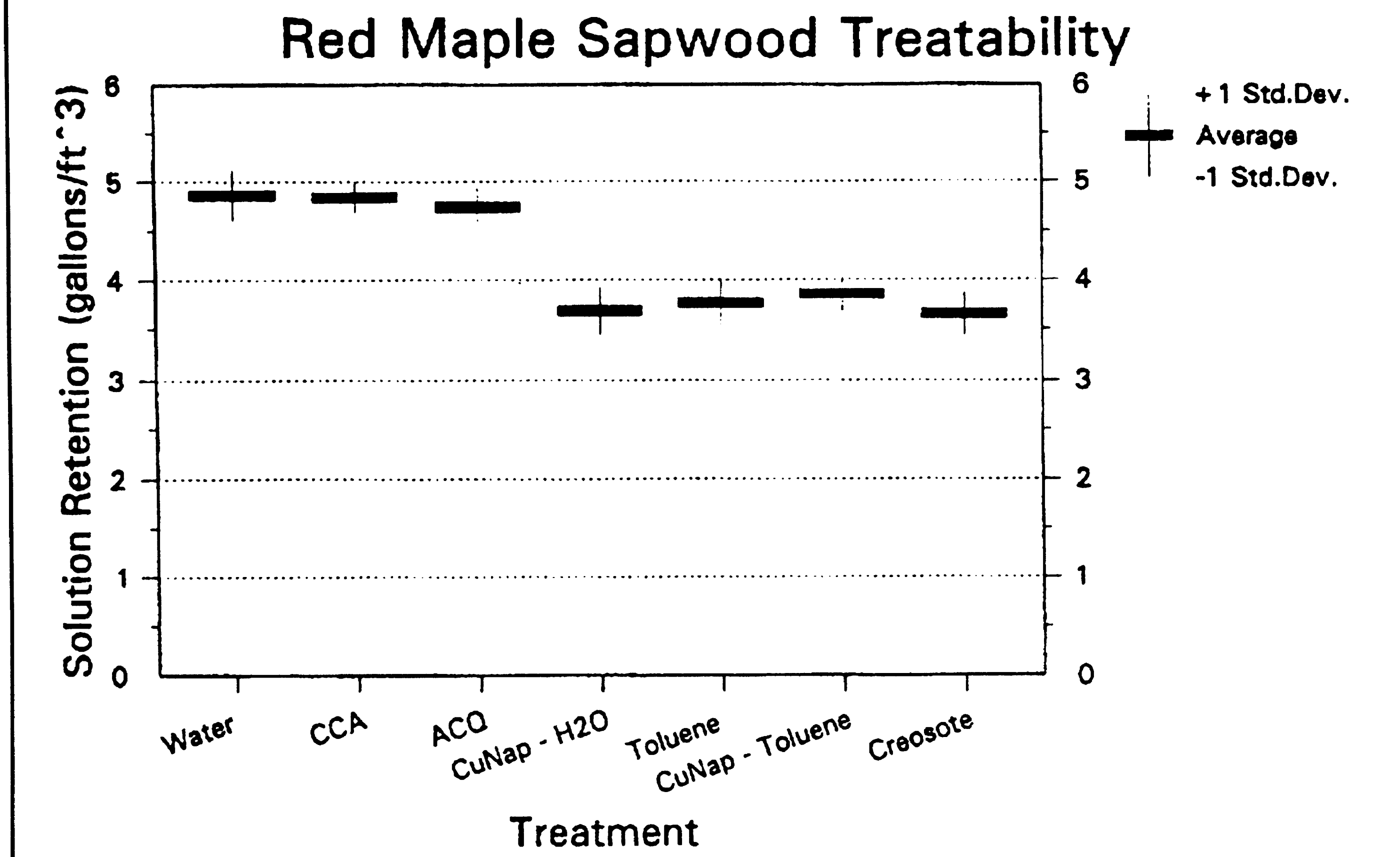
Rodney C. DeGroot, Plant Pathologist, USDA Forests Products Laboratory, Madison, WI.



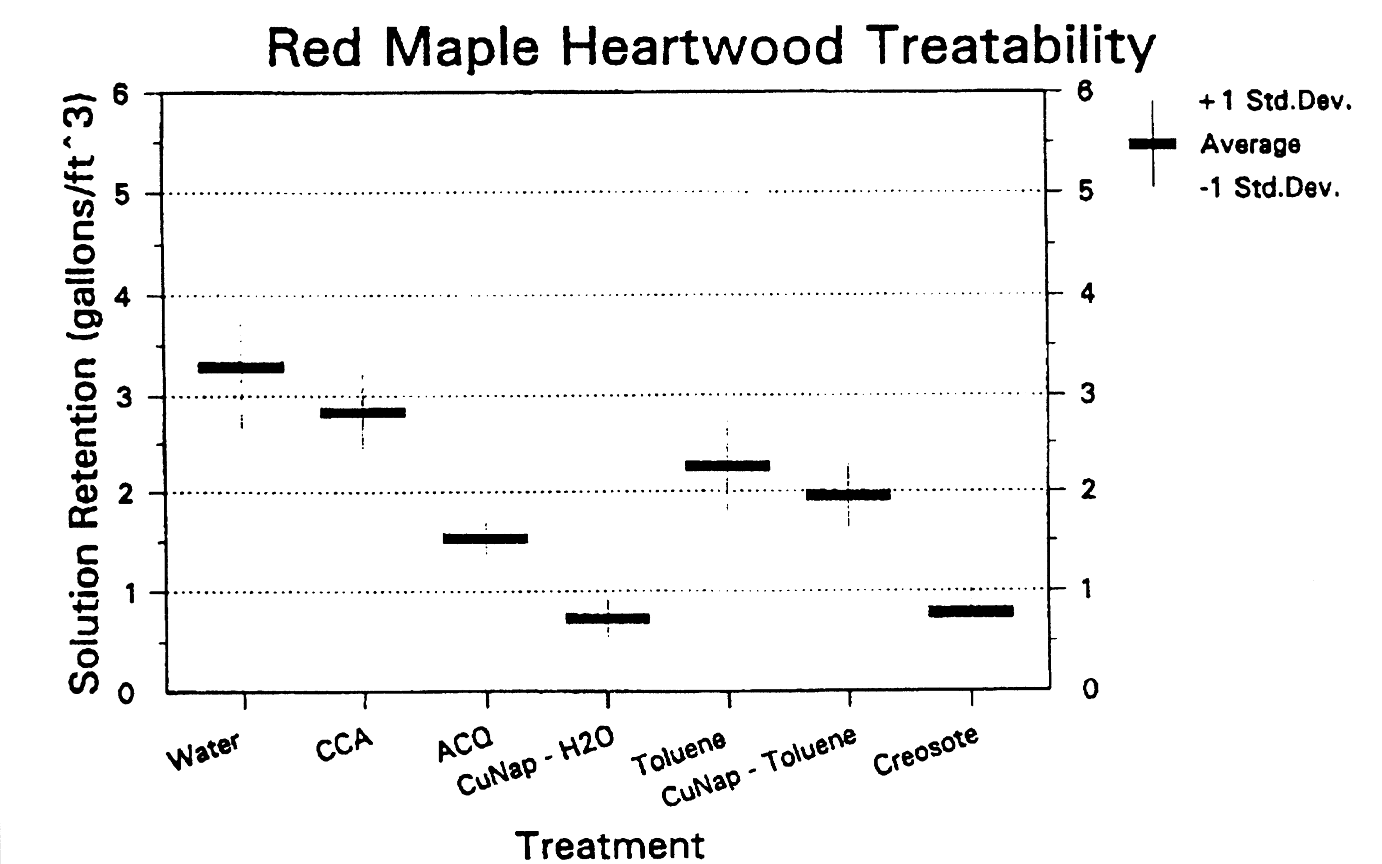
Red Maple Sapwood Treatability
Solution Retention (pcf)
0
10
20
30
40
50
+1 Std.Dev.
Average
-1 Std.Dev.
Water
CCA
ACQ
CuNap - H2O
Toluene
CuNap - Toluene
Creosote
Treatment



Red Maple Heartwood Treatability
Solution Retention (pcf)
0
10
20
30
40
50
+1 Std.Dev.
Average
-1 Std.Dev.
Water
CCA
ACQ
CuNap - H2O
Toluene
CuNap - Toluene
Creosote
Treatment

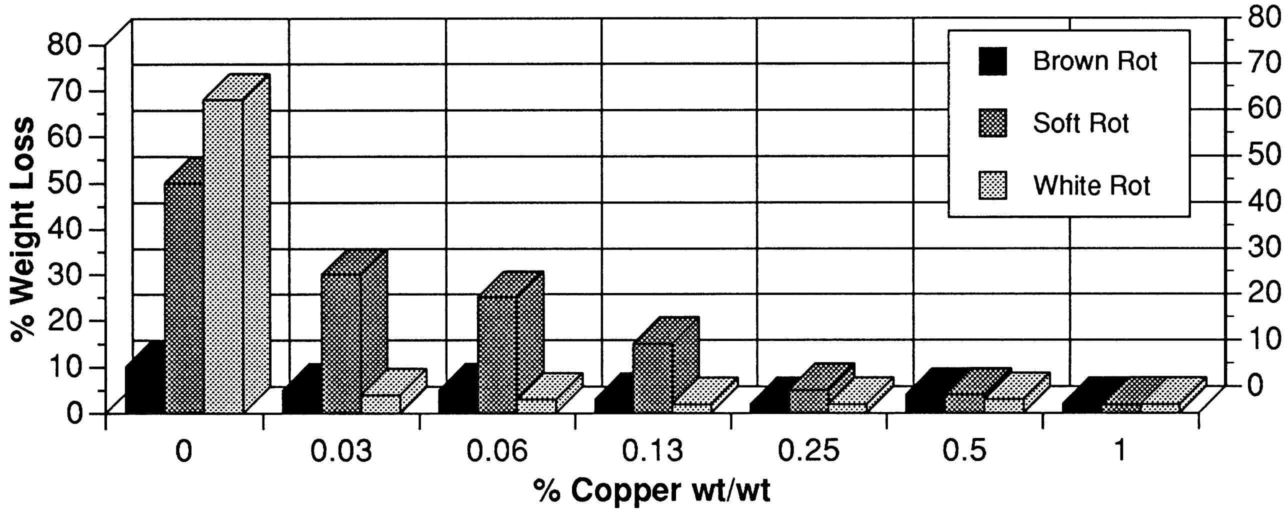


Red Maple Sapwood Treatability
Solution Retention (gallons/ft^3)
0
1
2
3
4
5
6
+1 Std.Dev.
Average
-1 Std.Dev.
Water
CCA
ACQ
CuNap - H2O
Toluene
CuNap - Toluene
Creosote
Treatment

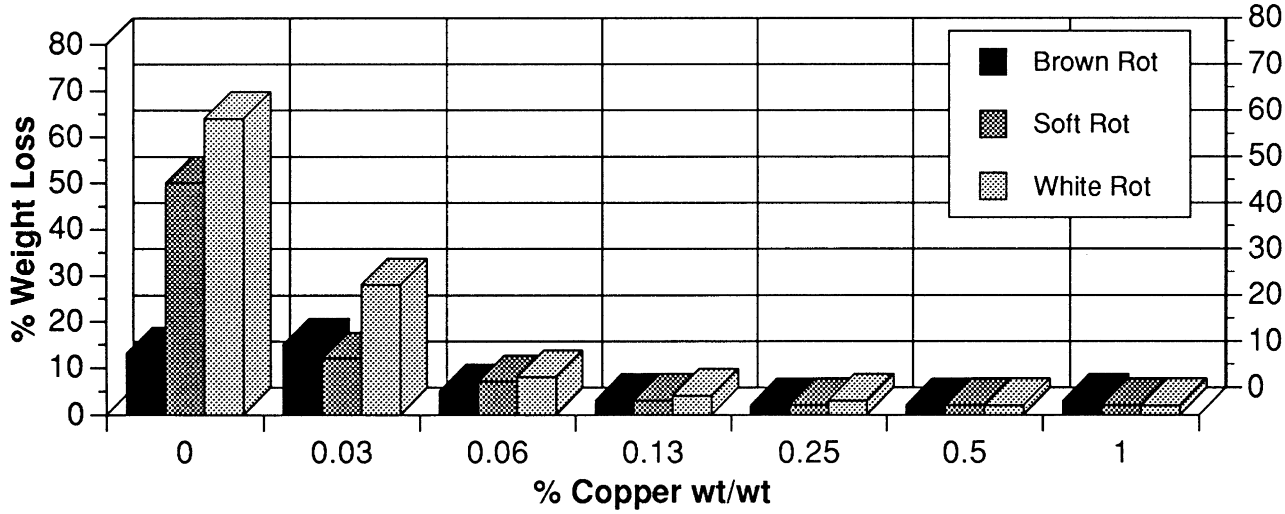


Red Maple Heartwood Treatability
Solution Retention (gallons/ft^3)
0
1
2
3
4
5
6
+1 Std.Dev.
Average
-1 Std.Dev.
Water
CCA
ACQ
CuNap - H2O
Toluene
CuNap - Toluene
Creosote
Treatment

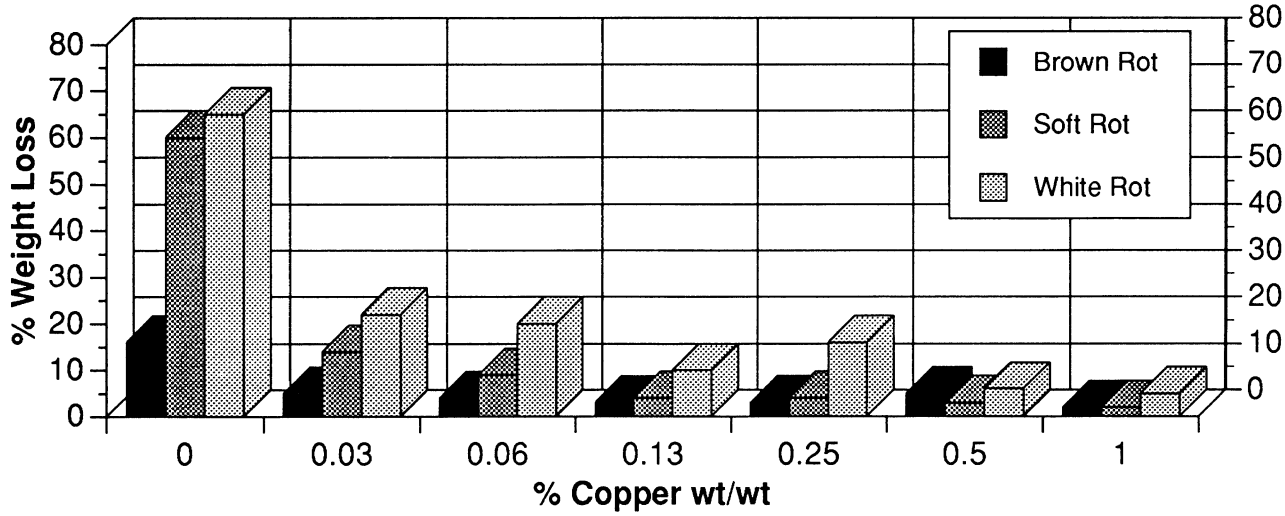
CCA-C TREATED RED MAPLE SAPWOOD



OIL-BORNE CuNap TREATED RED MAPLE SAPWOOD



WATER-BORNE CuNap TREATED RED MAPLE SAPWOOD



This page intentionally left blank.

Red Maple Strength (Stress) Studies

BACKGROUND

Underutilized northern hardwoods such as red maple have a great potential for use as construction materials. A major drawback to red maple's increased use in the past has been a lack of up-to-date strength (stress) information used by architects and engineers. Recently, two studies have been completed that significantly add to our knowledge about red maple's strength characteristics.

The first study was a cooperative project between the Northeastern Forest Alliance (NEFA) and the U.S. Forest Products Lab in Madison, WI. This project was headed by Dave Stevens and Jack Dwyer from the state of Vermont and Dave Green and Kent McDonald of the Forest Products Lab. In 1990, 9,000 Bd. Ft. of Vermont red maple was shipped to the Forest Products Lab for stress testing. The summary of the results of this test are included in "SECTION I" of this report.

The second study was conducted at Penn State University in cooperation with the Pennsylvania Department of Transportation. The results of this project were published in detail in January, 1992, under the title "SS-047, Preliminary Refinement of Hardwood Design Stress Values" by Dr. J.J. Janoviak, Dr. H.B. Manbeck, Dr. M.P. Wolcott, and Dr. J.F. Davolos. Highlights of this study are included in "SECTION II" of this report.

The results of both studies show that red maple is significantly stronger than current design values indicate - particularly in the lower grades. The major problem in gaining widespread industry acceptance, however, is overcoming the shortcomings associated with "visually grading" lumber to determine its strength characteristics. Visual grading is shown by these studies to be an inaccurate way to determine lumber strength.

There is currently a much more accurate way to test lumber for strength called Machine Stress Rating (MSR). Machine Stress Rating, while used extensively on the West coast, is a new technology in the Northeastern United States.

It is NEFA's hope that this report will stimulate interest in using red maple for its strength characteristics. In addition, we recognize that in order for this to happen, industry acceptance of alternatives to "visual grading", such as Machine Stress Rating, must probably occur first.

SECTION I. – SUMMARY REPORT OF NEFA RED MAPLE STRESS PROJECT CONDUCTED BY THE U.S. FOREST PRODUCTS LAB

Maple Yield

Conversion of red maple logs to profitable products, including structural dimension lumber, depends on knowledge about the expected yield from logs of various qualities. Results of this study reveal a high yield of nominal 2- by 4-inch lumber that meets or exceeds the light frame grade criteria from the USDA factory-grade F1 logs. From lower quality red maple logs, USDA factory-grade F2 and F3, just under half their volume was graded as structural lumber. The underutilized red maple timber resource could supply a structural-lumber products demand for residential housing markets and non-residential construction such as timber bridges.

Improved methods are needed for sorting logs into quality classes for the production of structural lumber. In this study, the available USDA factory log grading system was used because it would permit comparison with factory lumber yields from the same log set. Yield of 2- by 4-inch dimension lumber by log grade for all diameter classes was 55 percent No. 2 and better for F1 logs; 28 percent for F2 logs; and 20 percent for F3 logs. Including No. 3 dimension lumber grade, the yields were 73 percent for F1; 56 percent for F2; and 62 percent for F3.

Properties

Red maple is a medium density hardwood with nailing and machining properties similar to those of Southern Pine. Efficient utilization of hardwood structural lumber depends upon developing better procedures of grading and property assignment. The red maple study evaluated the properties of 2 x 4's tested in bending and in tension and compression parallel to the grain.

Compared to published values derived by ASTM D245 clear-wood procedures, the results indicate that significant increases in allowable properties could be obtained using procedures based on tests of full-size lumber (ASTM D1990).

Property estimates	Grade	Number	Ratio 2x4 test to D245 estimate
MOE	SS	114	1.07
	No. 2	305	1.14
	No. 3	197	1.27
MOR	SS	46	0.89
	No. 2	128	1.45
	No. 3	83	2.16
UTS	SS	20	1.63
	No. 2	49	2.62
	No. 3	32	2.31
UCS	SS	48	1.68
	No. 2	128	1.67
	No. 3	82	4.12

STRENGTH RATIOS OF VERMONT RED MAPLE 2 X 4'S

The results also demonstrate that the relationship between the grain (UCS) and bending strength (MOR), and between tension parallel to the grain (UTS) and bending strength are similar to those for softwood species. However, full size testing of visually-graded red maple using ASTM D1990 procedures presents several problems.

First is the huge cost of such a program. A full program would require sampling 360 pieces of lumber in three sizes (2x4, 2x8, and 2x10) and two grades (Select Structural and No. 2) for each of three test modes (bending, tension, and compression). The material cost alone of these 6,480 pieces of lumber is estimated at over $100,000.

Second, it is not likely that new values in the National Design Specifications (NDS) could be calculated for red maple obtained only from Vermont. The sample would have to be obtained from throughout the growth range.

Finally, the sticky problem of separating red maple from the weaker silver maple would make it difficult to avoid being conservative when assigning design values to visually-graded structural lumber.

Conservative equations given in D1990 for estimating UCS and UTS from MOR could reduce the cost of testing visually-graded lumber by two-thirds. However, the other two problems remain. These problems warrant looking further at the possibility of using machine grading techniques to stress grade lumber.

Machine Stress Rating

Utilization of visually-graded red maple structural lumber in house construction appears to be more dependent on development of yield data, the economics of alternative uses, and enhancement of user familiarity with species, rather than on development of higher design values. However, improved property estimates would enhance the use of red maple in engineered structures such as long span trusses and timber bridges.

Machine stress rating offers the possibility of improved properties without the problems of conducting an expensive testing program. It is also species-independent and therefore avoids the problem of identifying red maple from silver maple. Machine-stress-rated (MSR) lumber is lumber that has been evaluated by equipment that measures the stiffness of individual pieces of lumber. MSR lumber is distinguished from visually stress-graded lumber in that each piece is nondestructively tested and assigned allowable properties based on this test. MSR lumber is also required to meet certain visual requirements and conform to other provisions of the sponsoring grading agency, such as the Northeastern Lumber Manufacturers Association.

Machines that measure the MOE of each piece of lumber range from high production (1500 lineal feet per minute) to less expensive, but slower, systems. These slower systems are equally as good, and make it possible for low volume producers to consider entering into the marketplace with structural lumber of hardwood species, such as red maple.

To produce MSR lumber, the market or demand for a particular size and strength classification must first be identified. For example, red maple 2" x 6" lumber that meets a design specification of 1500 fb and 1,500,000 E (fb is extreme fiber stress in bending and E is the modulus of elasticity). Any mill considering this market would then get qualified by the governing agency to produce this grade.

The first production of MSR lumber from a hardwood species recently occurred at a mill in West Virginia. The mill was certified to produce 1200 f-1.2E and 1650 f-14E oak MSR for use in a timber bridge.

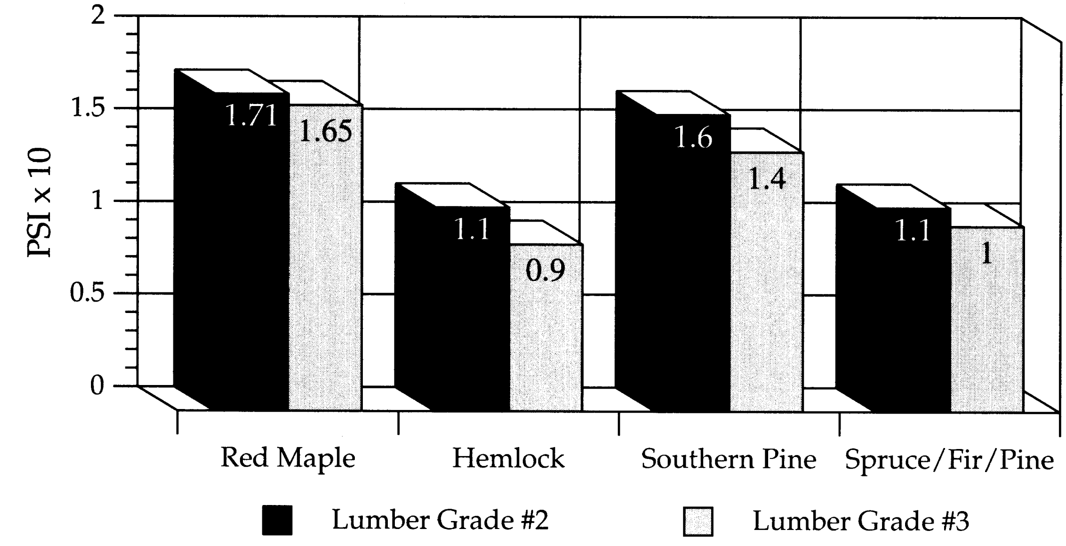
Using the MSR procedure, 2" x 9" lumber previously visually graded as No. 3 and better could have been assigned design values equivalent to those of Select Structural. Complete certification of the grade took place in less than one week.

To obtain additional information, contact: David W. Green or Kent A. McDonald, USDA Forest Service, Madison, WI. 53705 (608) 231-9309.

Additional Information

The following charts were developed by NEFA based on the results of Red Maple Stress testing at the Forest Products Lab in 1991. They show the relative strength characteristics of #2 and #3 grade, visually graded 2" x 8" lumber. The charts compare red maple to the commonly used construction lumber species of Hemlock, Southern Pine, and Spruce/Fir/Pine.

STIFFNESS COMPARISON
Modulus Of Elasticity

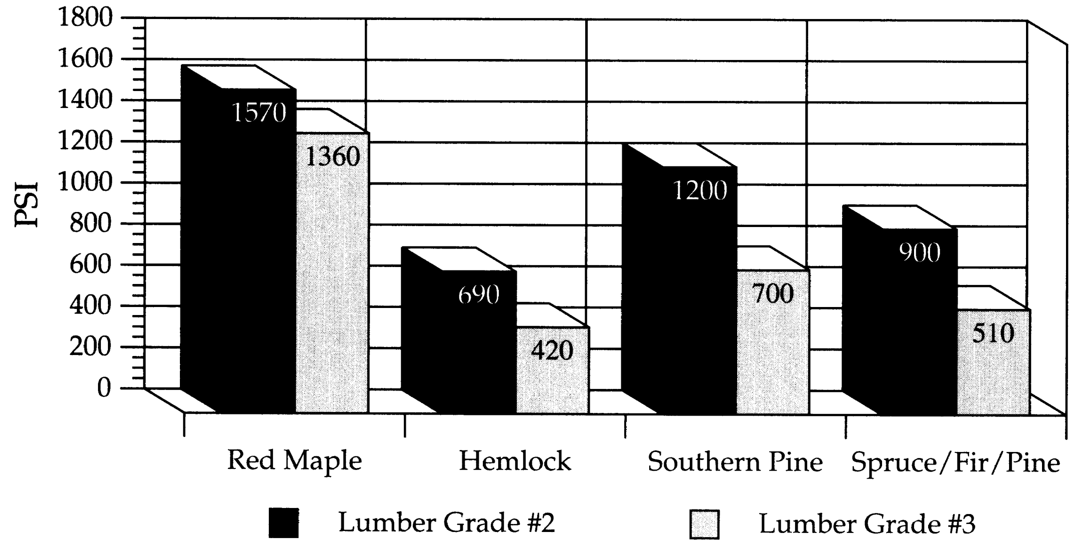


For visually graded dimension lumber.

*Red maple values taken from 1991 NDS supplement and increased by factors published in Table 2 of the paper. *Mechanical Properties of Red Maple 2x4's.*

All other values directly from 1991 NDS supplement.

STRENGTH COMPARISON
Extreme Fiber Bending

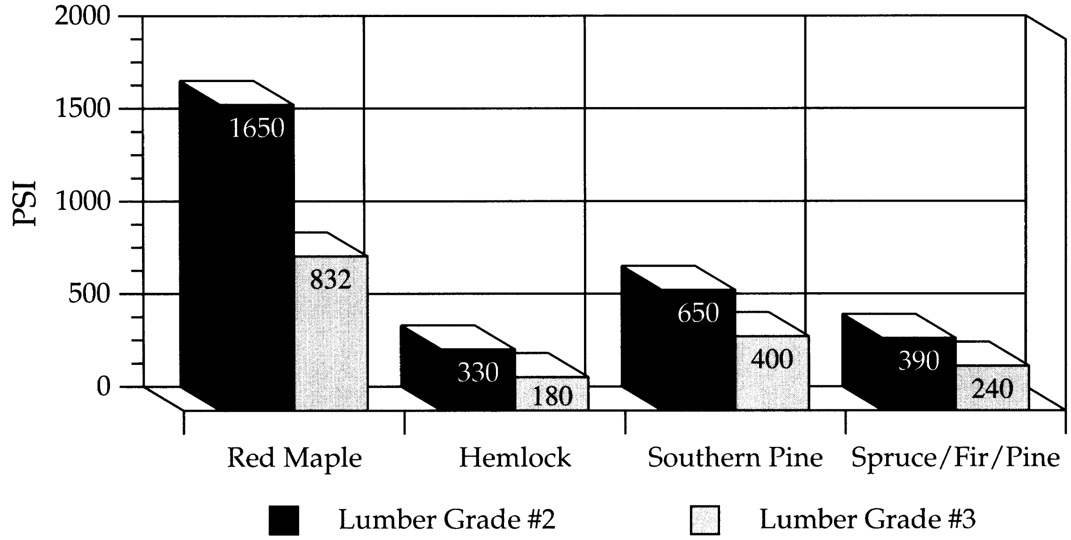


For visually graded 2x8's.

*Red maple values taken from 1991 NDS supplement and increased by factors published in Table 2 of the paper. *Mechanical Properties of Red Maple 2x4's.*

All other values directly from 1991 NDS supplement.

STRENGTH COMPARISON
Tension Parallel To Grain

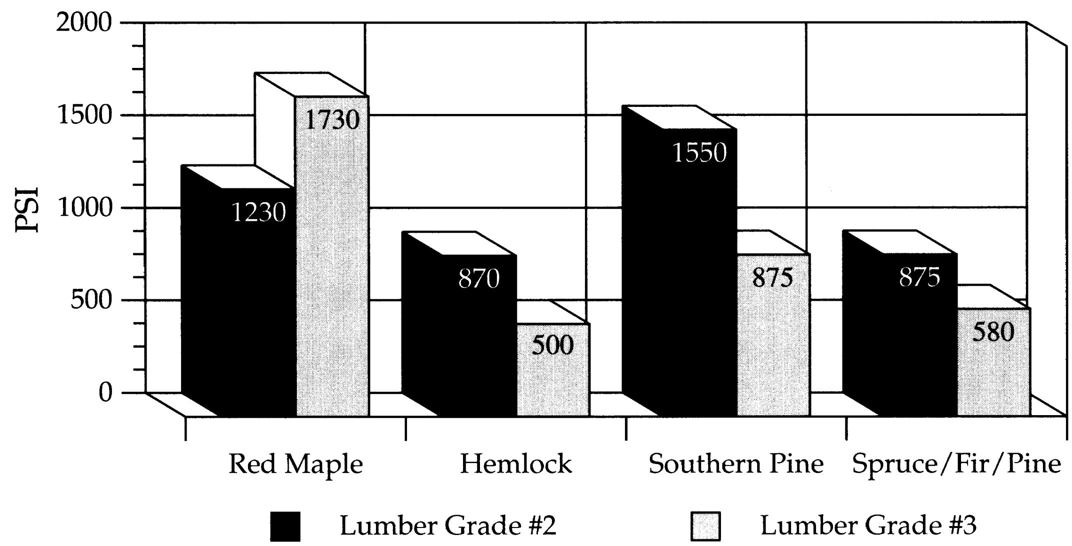


For visually graded 2x8's.

*Red maple values taken from 1991 NDS supplement and increased by factors published in Table 2 of the paper. *Mechanical Properties of Red Maple 2x4's.*

All other values directly from 1991 NDS supplement.

STRENGTH COMPARISON
Compression Parallel To Grain



For visually graded 2x8's.

*Red maple values taken from 1991 NDS supplement and increased by factors published in Table 2 of the paper. *Mechanical Properties of Red Maple 2x4's.*

All other values directly from 1991 NDS supplement.

SECTION II – PENN STATE UNIVERSITY STUDY

This section highlights the Penn State University Study "Preliminary Refinement of Hardwood Design Stress Values" by Janoviak, Manbeck, Wolcott and Davolos – Catherine Swatek, Project Manager.

Task 1– In-Grade Testing Versus Clear Specimen Procedures

INTRODUCTION

Task 1 research involved the destructive mechanical testing of full-sized red maple (Acer rubrum) lumber from two geographical areas in Pennsylvania (Allegheny and Northeastern). The objectives of Task 1 were to:

1. Determine the mechanical properties of select structural (SS) and #2 common (#2 C) red maple lumber in bending. The mechanical properties to be evaluated included modulus of elasticity (MOE), modulus of rupture (MOR), stress at the proportional limit (P_{pl}).
2. Determine the differences in the mechanical properties listed above for two structural lumber grades and geographical region.
3. Develope general normal, log normal and 3-parameter Weibull distributions describing the empirical data for MOE and MOR.
4. Compare MOE and MOR data from this project to current design values (E and F_b) determined using the in-grade testing with those determined using the small clear specimen method.

MATERIALS AND METHODS

Materials

Select structural and #2 common red maple 2" x 4" lumber, eight foot long, from two geographical areas in Pennsylvania were received from Pennsylvania State University (PSU). The lumber was graded in accordance with Northeastern Lumber Manufacturers Association (NELMA) rules by PSU.

Grade and Regional Comparison

A two-way analysis of variance (ANOVA) was used to compare properties between grades and regions. This analysis showed a statistical difference for MOE, MOR, and P_{pl} existed between the two grades. In all cases, the mechanical properties were greater for the select structural material than the #2 common.

A regional difference was shown to exist for MOE and P_{pl}, however, no significant difference existed between regions for MOR. In general, the regional differences were small and of no practical significance.

COMPARISON OF MOE AND MOR FROM IN-GRADE TESTING AND ADJUSTED CURRENT SMALL CLEAR WOOD SPECIMEN DESIGN VALUES

Property	Grade	In-Grade Value	Small Clear Wood Value[1]
MOE ($x10^6$ psi) (median)	SS	1.9	1.7
	No. 2	1.8	1.5
MOR (psi) (5% NTL)	SS	7,800	4,900
	No. 2	4,200	3,300

Computation of design values on the basis of small clear wood specimen data is presented in the Appendix section of the full report.

Median MOE values are approximately 10-20% greater through in-grade testing than current design values, however, differences in MOR are much larger. The in-grade values for MOR are 59% and 27% higher than current adjusted design values for select structural and #2 common grades respectively. Whereas increases for the softwood in-grade values tended to be greater for select structural than lower grades, in no case were increases as large as those found in this research. After examining the red maple select structural lumber from this project, an inordinate amount of defect-free boards were found. It is likely that the sampling for select structural in this project was not truly representative of the population. This bias combined with the limited geographic sampling may have contributed to the high strength values.

CONCLUSION

A total of 239 select structural and 192 #2 common red maple nominal 2" x 4" boards were tested using third-point static bending. Statistical distributions were developed for MOE and MOR by grade. Normal, log normal, and 3 parameter Weibull distributions were fit to the empirical data and reported. The in-grade testing data was then used to validate current design values developed with the small clear specimen method.

The lumber tested in this program possessed MOE and MOR values that substantially exceeded current design values. Although this data indicates conservative design stresses for nominal 2" x 4" lumber, sampling bias may have exaggerated actual differences. Further sampling over a larger geographic range is needed to validate these findings.

Task 2 – Visual Versus Other Nondestructive Grading Methods

INTRODUCTION

Task 2 for the sponsored research project included the initial responsibilities related to the log or raw material procurement, secondary lumber manufacture, drying, conditioning combined with experimental non-destructive testing of nominal 2" x 4" red maple for two structural VSR lumber product grades.

The two geographic forest inventory units sampled were: 1) Allegheny (2a); and 2) North-Central (2b). Inventory unit 2a encompasses Elk, Forest, McKean, and Warren counties; while 2b covers Centre, Clearfield, and Jefferson counties. Selection of these inventory units for the study was based on their substantial volumes of red maple sawtimber.

EXPERIMENTAL PROCEDURES

Visual Stress Grading

Visually stress-rated (VSR) lumber classification was conducted on the available supplies of processed nominal 2" x 4" red maple. Classification using visual inspection was accomplished using the NELMA lumber grading rules.

Specimen modulus of elasticity (MOE) values were determined using computed stress wave velocity (c) and density (p). From elastic one-dimensional wave theory, the empirical stress wave modulus is of the computational form:

Dynamic Stress Wave MOE = $c^2 p/g$, lbs/in^2

where c = wave velocity, in/sec,
p = material density, lbs/in^3, and
g = gravitational constant, 386 in/sec^2.

Lumber stress wave MOE values were computed using this relationship from the collected frequency, weight, dimensional properties.

Secondary, static load-deflection NDE testing for lumber stiffness determination was conducted after the completion of initial stress wave analysis. Long-span MOE values for both flatwise (plank) and edgewise (joist) lumber orientation were determined through use of a single center-point flexural beam test scheme.

Computation of lumber stiffness was based on the slope of the load deflection curves in solution for MOE for the constitutive beam deflection equation for center point loading. The static MOE computational equation based on beam deflection theory is of the generalized form:

Static MOE (flatwise or edgewise) = $PL^3/48(Y)I$

where P = applied load, lbs,
L = beam span, in,
Y = differential deflection, in,
$I = bh^3/12$ or moment of inertia,
b = plank or joist width, in, and
d = plank or joist depth, in.

Experimental lumber stiffness for derived MOE flatwise and edgewise are apparent values with no correction for shear deformations. Percentage MOE measurement error have been assumed as negligible given the large, L/d, span to depth ratios.

EXPERIMENTAL RESULTS

RED MAPLE LUMBER STIFFNESS BETWEEN SAMPLED GEOGRAPHIC UNITS

TABLE 1. Descriptive Statistics[1] for NDE Test Results on Nominal 2" x 4" Red Maple from the Allegheny Geographic Unit.

Property[2] Variable	Mean Value	Standard Deviation	Maximum Value	Minimum Value
VSR Grade – SS[3]	-------	-------x10⁶	psi-------	-------
Flatwise MOE	1.911	0.264	2.610	1.300
Edgewise MOE	1.760	0.238	2.350	1.050
SWMOE	1.913	0.242	2.450	1.430
VSR Grade – No. 2[4]				
Flatwise MOE	1.951	0.385	2.850	0.958
Edgewise MOE	1.708	0.360	2.290	0.713
SWMOE	1.635	0.329	2.350	0.692

1 Numerical values are rounded to the nearest thousand psi.
2 Property values for SS and No. 2 grade materials are based on an average % moisture content of 11.2 and 12.6, respectively.
3 Sample size equals 119 total Select Structural VSR specimens.
4 Sample size equals 106 total No. 2 VSR specimens.

TABLE 2. Descriptive Statistics[1] for NDE Test Results on Nominal 2" x 4" Red Maple from the Northcentral Geographic Unit.

Property[1] Variable	Mean Value	Standard Deviation	Maximum Value	Minimum Value
VSR Grade – SS[3]	-------	-------x10⁶	psi-------	-------
Flatwise MOE	1.962	0.223	2.490	1.300
Edgewise MOE	1.825	0.198	2.380	1.250
SWMOE	1.980	0.222	2.510	1.420
VSR Grade – No. 2[4]				
Flatwise MOE	1.758	0.237	2.700	1.200
Edgewise MOE	1.652	0.212	2.730	1.160
SWMOE	1.807	0.199	2.210	1.280

1 Numerical values are rounded to the nearest thousand psi.
2 Property values for SS and No. 2 grade materials are based on an average % moisture content of 12.7 and 13.9, respectively.
3 Sample size equals 122 total Select Structural VSR specimens.
4 Sample size equals 95 total No. 2 VSR specimens.

TASK 2 SUMMARY

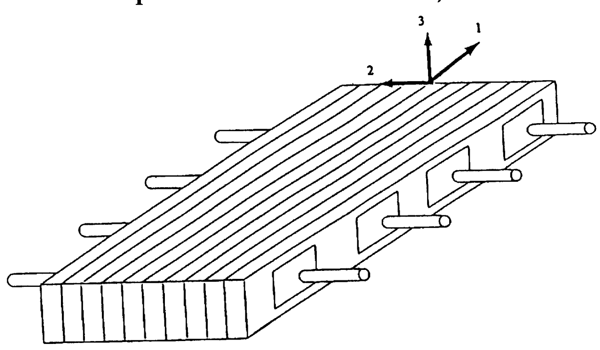
Statistical analysis results strongly suggest the lack of an apparent trend for substantial differences in lumber stiffness on the strict basis of geographic origin. Average MOE values for both lumber joist and plant test orientation between the sampled Allegheny (2a) and Northcentral (2b) forest inventory units were found for most instances to be of less than significant difference using DMRT statistical comparisons. Regression analysis identify that stress wave NDE provides an effective methodology with useful correlation for the static MOE prediction in either joist or plank load orientations.

Task 3 – Strength and Stiffness Properties for Stress-Laminated Decks Made of Select Structural Red Maple (Acer rubrum)

INTRODUCTION

Stress-laminated timber bridge decks are a relatively new concept in timber bridge design. Developed originally in Canada in 1976 for rehabilitation of nail-laminated decks, the transverse stressing of a laminated timber deck allows adequate load transfer, above and beyond nail lamination, as well as efficient use of smaller length timber laminae. To analyze and design a stress-laminated timber deck as an orthotopic plate, six independent elastic constants are needed to include shear effects in the analysis. The Orthotopic representation of a stress-laminated deck with three material directions is shown in Figure 1.

FIGURE 1 – Stress Laminated Beam With Principal Material Directions 1, 2 and 3.



OBJECTIVES

The objectives of Task 3 were as follows:

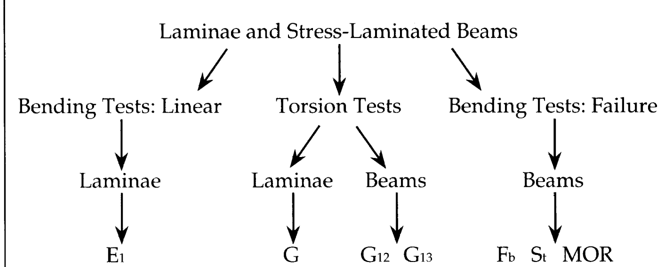
1. To determine representative values of longitudinal stiffness (including shear) and strength of stress-laminated beams of two widths for select structural red maple. Specifically, the following data will be obtained: Modulus of elasticity E_1, shear moduli G_{12}, and G_{13}, allowable bending strength F_b, proportional limit bending strength S_p, and modulus of rupture MOR (ultimate bending strength).
2. To correlate the bending stiffness and strength of the laminated beams with the in-grade testing results provided by Tasks 1 and 2.
3. To propose mathematical correlations between the in-grade design data and the laminated beam design data obtained in this task.
4. To propose test methods to determine the stiffness and strength properties of stress-laminated decks that can be used in a follow-up large scale research program. The proposed test methods will include guidelines for determination of the transverse elastic modulus E2 and shear modulus G_{23}.

EXPERIMENTAL PROCEDURES

The lumber material used in Task 3 consisted of 104 pieces of select structural red maple of 2" x 4" x 10' nominal dimension. The laminae are first non-destructively tested by utilizing an "E"-Computer, dead-load deflection, and torsion to determine the elastic modules E_1 and shear modulus G of each laminae (Figure 2).

The experimental program was organized in two phases as shown in Figure 2. The first phase consisted of testing the lumber laminae and stress-laminated beams in bending and torsion. The second phase was concerned with the testing of stress-laminated beams to failure.

FIGURE 2 – Experimental Program



Laminae Testing Results

Table 1 gives the mean, standard deviation, and coefficient of variation for the elastic modulus E_1 and the shear modulus G of the laminae computed from bending and torsion tests:

TABLE 1. Statistical Results of Laminae Bending and Torsion Tests[1]

Test Value	Mean ($\times 10^6$ psi)	Std. Dev. ($\times 10^5$ psi)	Coefficient of Variation (%)
Apparent E	1.84	2.77	15
True E	1.89	3.52	18
E-computer	2.05	2.99	15
Average Shear Modulus	0.214	0.231	11

Discussion of Results

The data obtained for the bending tests of the laminae show that the effect of shear deformation for 2" by 4" by 10' select structural red maple is negligible. It appears that the "E" computer can be used as an effective tool for determining the modulus of elasticity. The shear modulus from torsion tests show no direct correlation between the properties for the individual boards and the stress-laminated beam properties. The plate tests used by previous researchers for the determination of shear modulus G^{12} is difficult to implement and prone to errors, whereas the torsion solution proposed in this study is simple and accurate. With the developments found in this study, all five required constants can be obtained following the suggestions provided in this report. Moreover, the assumption of transverse isotropy for structural lumber, as proposed by Davalos (1990), appears to be accurate, and torsion tests should be used to compute the shear moduli for various species and grades.

IMPLEMENTATION PLAN

1. This project has demonstrated that in-grade testing provides for greater design efficiency through less conservative flexural properties for structural light framing red maple 2x4 lumber. One recommendation to further promote the structural use of underutilized hardwoods is to expand the in-grade data base. Further efforts are needed on several more geographic regions to support the inclusion of in-grade red maple values into the National Design Specification (NDS). Expanded research should consider testing of at least one additional lumber product nominal size class (i.e., 2x6) along with assessed refinement of other design properties (i.e. UTS and UCS). Other optional hardwoods of underutilized status and materials generally unsuitable for appearance lumber commodity sale should be studied for possible structural applications. More immediate consideration should be given for consolidation of experimental results with data being collected at the Forest Products Laboratory (Madison, Wisconsin) on red maple sampled from Vermont. Combining the two data bases would present greater evidence to support the ultimate inclusion of in-grade based red maple values within the NDS supplement for standard structural practice.

2. The project has developed useful predictive regression equations to predict static load red maple lumber stiffness. Project results provide the basis for an alternative stiffness grading procedure for possible mill production operations. A recommendation is made that future mill operations consider this optional procedure as a rapid method to assess lumber grade production. The hardwood industry, before entering the structural lumber market, may wish to explore the establishment of MSR grading for higher product quality assurance with potentially higher design values for a more competitive posture over VSR lumber. The Pennsylvania Department of Commerce should consider encouraging lumber processors to examine the production of structurally graded lumber from underutilized hardwoods. Assistance should be given to those operations which are willing to risk capital for an emerging structural lumber market based on lessor utilized hardwood materials.

3. The stressed deck structural data should be used to promote the revision of the repetitive use adjustment factor for the specific design practice of stress-laminated and glue-laminated bridge decks. In addition, efforts directed from the research findings should be used as a basis to establish simple and reliable standard procedures for computation of all the shear moduli constants and transverse modulus E_2. The torsion procedure used in this study has shown that it can be used to derive G_{12} and G_{13}. Transverse modulus may be computed from a cylindrical bending test with deck element supported on the edges parallel to the lamination. Further torsional loading deck research in a more comprehensive study should evaluate the parameters of depth-to-width ratio of lumber components, stressing bar spacing, lower lumber grades, and at least additional species. Also, it is noted that additional efforts are needed to conduct more comprehensive experimentation to establish the bending strength of stress-laminated and glue-laminated vertical deck assemblies. Deck specimens of three widths constructed of lower grade material should be studied.