

MACHINE GRADING OF DIMENSION LUMBER

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INTRODUCTION

Wood has considerable variation in respect to both its physical and chemical properties. Variation among different species is well recognized, e. g. Douglas-fir and western red cedar. Less frequently recognized are the differences within the same species or within a single tree. Even with our modern-day technology these properties are very difficult, if not impossible, to control. Therefore, to use wood as an engineered product a means of segregating the individual pieces according to their capabilities has been devised. This system of segregation is called lumber grading; more specifically in respect to dimension lumber it is called stress-grading.

The current visual stress-grading methods have been developed over a period of many years and as a result of many hundreds of strength tests performed by several research laboratories. These destructive strength tests were performed on small, clear, straight grain specimens. After making the appropriate reductions for such factors as variability, long-time loading, and accidental overloading a basic-stress for clear pieces of one species of wood were obtained. The basic stress was further reduced to a working stress according to the particular stress-grade assigned. Here such factors as knot frequency and size, slope of grain, or degree of checking determines the amount of reduction of the basic-stress.

Our current system of stress-grading lumber then is based on an ultra-conservative approach to be sure that no extremely weak pieces of lumber are used where high strength is required. The present day system is effective in eliminating the weak pieces; however, the price we pay for this system is conservatism.

For example, in stress grades of certain structural species it is not unusual to find pieces that are five to six times as strong as the weakest pieces. The average strength has been found in some species to be almost three times as strong as the weakest piece. Utility grade Douglas-fir under the Federal Housing Administration's Minimum Property Standards has an allowable stress of 200 p. s. i. in bending, but some pieces have tested as high as 10,000 p. s. i.

The stiffness of lumber is another important design function which is often under rated. One value for stiffness has been established for each species with little or no regard to the effect of knots, slope of grain, or other strength reducing defects. Potlach's studies on stiffness have shown that some individuals will be almost twice as stiff as the average and that a considerable overlapping between visual grades exists.

In view of the ever increasing competition in the structural field, wood can no longer afford the ultra-conservative practices of the past. New methods are needed which can accurately and rapidly determine the strength properties of wood. A form of automation must be introduced to lumber grading which will non-destructively test each piece of lumber and segregate the lumber according to

its structural capabilities.

ONE COMPANY'S APPROACH TO NONDESTRUCTIVE TESTING

Several methods of nondestructively testing wood have been investigated by several agencies and have had varying degrees of success. These methods include specific gravity considerations, vibrational techniques, sonic testing, proof loading, and stiffness considerations.

The approach used by Potlatch Forests, Inc. has been to determine if a valid relationship exists between stiffness (modulus of elasticity times moment of inertia) and modulus of rupture which ultimately determines the bending stress or f value.

There are two basic reasons for choosing stiffness as the means of nondestructive testing dimension lumber. First, stiffness is probably the most important design property of wood. Approximately 75 per cent of framing lumber used in house construction today is limited by stiffness. Second, stiffness is the only structural property of wood that can be determined by a nondestructive test. All other structural properties require a destructive test for their determination.

A rather extensive testing program was undertaken with the help of five independent laboratories to investigate the relationship between stiffness and modulus of rupture. Studies were performed on several structural grades and sizes of Douglas-fir, western larch, western hemlock, white fir, and southern pine. Also investigated were moisture content effects and joist versus plank considerations. Two laboratory models of a nondestructive testing machine were built to expedite the testing and establish the feasibility of machine grading lumber.

These hundreds of destructive tests proved that a very close relationship does exist between stiffness and modulus of rupture. The relationship was so close for the Western Pine Association species tested that the effect of species could essentially be eliminated. In other words, one table for most structural properties could be used for all species tested.

Derivation of the working stresses followed the standard practice as recommended by American Society of Testing Materials. Reducing factors for variability of modulus of rupture, duration of load, and accidental overload were included.

After establishing that a valid relationship exists between stiffness and bending stress the manufacture of a production machine was given to Industrial Sciences, Portland, Oregon. The first Continuous Lumber Tester (CLT-1) was delivered to Lewiston, Idaho in October, 1962.

The Continuous Lumber Tester determines the modulus of elasticity of dimension lumber by measuring the force required to bend it a given amount. The roller system deflects the board as a plank 5/16-inch in one direction on the entrance side of the machine. As the board progresses through, it is again deflected 5/16-inch in the opposite direction in order to average the effects of natural bow. The force required to do this bending is continuously measured by two transducers. Each transducer is sampled every six inches of board length; these samples are retained and averaged in the storage system. When the measurement is complete, the voltage in the storage system is fed into the grader electronics which in turn activates the proper E-grade stamp.

To prevent an extremely weak area from being masked by surrounding high strength material, a low point detector has been incorporated into the electronic system. Regardless of what the average output from the two transducers is, each E-grade must have the lowest reading above a minimum level or the board will be graded in the next lower grade.

The CLT-1 can grade lengths from eight to twenty-six feet, and widths from 2 x 4 through

2 x 12. Random lengths can be handled without special adjustments, but width requires the turning of a handwheel selector. The CLT-1 can grade at speeds up to 1000 lineal feet per minute.

IMPLICATIONS OF MACHINE GRADING

What will machine grading of dimension lumber mean to the lumber industry and lumber users? To the manufacturer, machine grading will 1) provide an accurate classification of lumber according to strength capabilities; 2) reduce the cost of stress-grading; 3) improve net realization; 4) enable lumber to hold old and gain new markets for structural uses; 5) improve salability due to 100% inspection; 6) enable the use of certain species for structural purposes which today are not fully accepted as such.

To the user of dimension lumber machine grading will mean 1) lower in-place-costs because of wider joist spacings, substitution of a smaller size, or longer spans; 2) simplification of span tables, lumber grades, and other technical data; 3) assurance of dependability for the architect, engineer, builder, and building official; 4) automatic compensation of effects of moisture content and size.

National Design Specification for Stress-Grade Lumber and Its Fastenings publishes twenty different f-values for Douglas-fir, western larch, western hemlock, white fir, and southern pine. The Federal Housing Administration's Minimum Property Standards publishes thirty-four different f-values for the same species. Machine grading is intended to replace this conglomeration of different f-values with a few relatively simple E-grades. Some E-grades will carry a much higher stress-rating than those currently given to wood and therefore give it a much better competitive position with respect to other materials.

Table I gives the allowable spans for the species indicated by E-grades. This one table condenses some 20 tables of FHA Minimum Property Standards.

Trussed rafters present an area which can greatly benefit from machine grading. The limiting properties of wood in trussed rafters are tension, compression parallel to the grain, and fiber stress in bending. Under machine grading structural lumber of such quality and assurance of performance will be available to the truss fabricator that longer spans or wider truss spacings not formerly feasible will now be practical.

The role of moisture content will have a very significant place in machine graded lumber. Wood increases in strength per unit area as the moisture content decreases below the fiber saturation point. However, shrinkage of the wood decreases the cross-sectional area. These two factors, increase in strength and loss of cross-sectional area, tend to compensate one another. To take full advantage of the drying effect, lumber should be dried to as low moisture content as practical, surfaced, and then machine graded.

To show the advantage of drying to a low moisture content, approximately eight thousand feet of white fir 2 x 4 Utility and Better was separated into two moisture content groups. This was accomplished by a Laucks Sentry Continuous Moisture Detector set to reject at the twelve per cent moisture content level. The two groups were then graded in the Continuous Lumber Tester with the following results:

<u>Moisture Content Range</u>	<u>Yield By Percentage of CLT-1 Grades</u>				<u>Total No. of Pieces</u>
	<u>E-2.2</u>	<u>E-1.8</u>	<u>E-1.4</u>	<u>E-1.0</u>	
	<u>f 2700</u>	<u>f 2100</u>	<u>f 1500</u>	<u>f 900</u>	
	%	%	%	%	
Less than 12%	3	32	54	11	263
Over 12%	1	13	62	24	356

TABLE I

TABLES OF MAXIMUM ALLOWABLE SPANS

FOR

POTLATCH ELECTRO-MECHANICAL STRESS-RATED LUMBER

DOUGLAS FIR, LARCH, WHITE FIR, WESTERN HEMLOCK, AND SOUTHERN PINE

FLOOR JOISTS

Nominal Size Inches	Spacing Inches	40 PSF LIVE LOAD*					30 PSF LIVE LOAD*				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 x 6	12"	12-0	11-3	10-6	9-8	8-8	12-11	12-2	11-4	10-5	9-4
	16"	10-10	10-3	9-7	8-9	7-10	11-9	11-0	10-3	9-5	8-6
	24"	9-6	9-0	8-4	7-8	6-10	10-3	9-8	9-0	8-3	7-4
2 x 8	12"	16-0	15-4	14-5	13-3	11-10	16-11	16-3	15-5	14-3	12-9
	16"	14-10	14-0	13-1	12-0	10-9	15-8	15-1	14-0	12-11	11-6
	24"	13-0	12-3	11-5	10-6	9-5	13-11	13-3	12-4	11-4	10-1
2 x 10	12"	19-1	18-3	17-5	16-4	15-0	20-2	19-4	18-5	17-3	16-0
	16"	17-9	17-0	16-2	15-2	13-8	18-9	18-0	17-2	16-0	14-8
	24"	16-0	15-4	14-6	13-4	11-11	16-11	16-3	15-6	14-4	12-9
2 x 12	12"	21-11	21-0	20-1	18-11	17-5	23-2	22-3	21-4	20-0	18-4
	16"	20-4	19-7	18-8	17-7	16-2	21-7	20-8	19-10	18-7	17-1
	24"	18-5	17-8	16-11	15-11	14-4	19-6	18-8	17-11	16-10	15-6

* Plus 10 PSF dead load.

FOR FLOOR JOISTS DESIGNED ON BASIS OF F.H.A. MINIMUM PROPERTY STANDARDS
REQUIREMENTS: TOTAL DESIGN LOAD USED FOR BOTH STRESS AND DEFLECTION
DEFLECTION = 1/360 SPAN TO 15 FEET; 1/2" MAXIMUM IN LONGER JOISTS

TABLE MAY BE USED FOR INLAND DOUGLAS FIR, GRAND FIR, WESTERN LARCH AND WESTERN HEMLOCK

CEILING JOISTS

Nominal Size Inches	Spacing Inches	No Attic Storage*					Limited Attic Storage**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 x 4	12"	13-6	12-10	12-0	11-0	9-10	10-9	10-2	9-6	8-9	7-10
	16"	12-3	11-8	10-11	10-0	9-0	9-9	9-3	8-8	7-11	7-1
	24"	10-10	10-2	9-6	8-9	7-10	8-6	8-1	7-7	7-0	6-0
2 x 6	12"	19-0	18-4	17-4	16-3	14-11	16-0	15-4	14-5	13-3	11-10
	16"	17-8	16-11	16-1	15-2	13-7	14-10	14-0	13-7	12-0	10-9
	24"	16-0	15-4	14-5	13-3	11-10	12-11	12-3	11-5	10-6	9-1
2 x 8	12"	23-11	23-0	21-10	20-6	18-10	20-2	19-4	18-4	17-3	15-10
	16"	22-4	21-5	20-4	19-1	17-7	18-9	18-0	17-1	16-1	14-8
	24"	20-2	19-4	18-4	17-3	15-10	16-11	16-3	15-5	14-4	12-4
2 x 10	12"	28-7	27-5	26-1	24-6	22-6	24-1	23-1	21-11	20-7	18-10
	16"	26-8	25-6	24-3	22-10	21-0	22-5	21-5	20-5	19-2	17-8
	24"	24-1	23-1	21-11	20-7	18-10	20-2	19-5	18-5	17-4	15-7

* Slope of roof is 3 in 12 or less. 15 PSF total design load.
** Slope of roof is 3 in 12 or greater. 20 PSF live load + 10 PSF dead load

FOR CEILING JOISTS DESIGNED ON BASIS OF F.H.A. MINIMUM PROPERTY STANDARDS
REQUIREMENTS: TOTAL DESIGN LOAD USED FOR BOTH STRESS AND DEFLECTION
DEFLECTION = 1/240 SPAN TO 15 FEET; 3/4" MAXIMUM IN LONGER JOISTS

TABLE MAY BE USED FOR INLAND DOUGLAS FIR, GRAND FIR, WESTERN LARCH AND WESTERN HEMLOCK

LOW SLOPE ROOF JOISTS

Nominal Size Inches	Spacing Inches	Not Supporting Finished Ceilings*					Supporting Finished Ceilings**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 x 6	12"	16-0	15-4	14-5	13-3	11-10	15-4	14-8	13-8	12-7	11-3
	16"	14-10	14-0	13-1	12-0	10-9	14-1	13-4	12-5	11-5	10-3
	24"	12-11	12-3	11-5	10-6	9-1	12-1	11-8	10-10	10-0	8-5
2 x 8	12"	20-2	19-4	18-4	17-3	15-10	19-4	18-7	17-8	16-7	15-3
	16"	18-9	18-0	17-1	16-1	14-8	18-0	17-4	16-5	15-5	13-11
	24"	16-11	16-3	15-5	14-4	12-4	16-9	15-11	14-10	13-8	11-5
2 x 10	12"	24-1	23-1	21-11	20-7	18-10	23-2	22-2	21-1	19-10	18-3
	16"	22-5	21-5	20-5	19-2	17-8	21-6	20-8	19-8	18-5	16-11
	24"	20-2	19-5	18-5	17-4	15-7	19-5	18-9	17-9	16-8	14-5
2 x 12	12"	27-9	26-8	25-4	23-10	21-10	26-8	25-7	24-4	22-10	21-0
	16"	25-10	24-9	23-7	22-2	20-4	24-10	23-10	22-8	21-3	19-7
	24"	23-4	22-4	21-3	20-0	18-4	22-5	21-6	20-2	19-3	17-5

* 20 PSF live load + 10 PSF dead load.
** 20 PSF live load + 15 PSF dead load.

FOR LOW SLOPE ROOF JOISTS DESIGNED ON BASIS OF F.H.A. MINIMUM PROPERTY STANDARDS
REQUIREMENTS: TOTAL DESIGN LOAD USED FOR BOTH STRESS AND DEFLECTION
DEFLECTION = 1/240 SPAN UP TO 15 FEET; 3/4" MAXIMUM FOR LONGER SPANS

TABLE MAY BE USED FOR INLAND DOUGLAS FIR, GRAND FIR, WESTERN LARCH AND WESTERN HEMLOCK

RAFTERS

Nominal Size Inches	Spacing Inches	Light Roofing*					Heavy Roofing**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 x 4	12"	13-1	12-5	11-7	10-8	9-7	11-10	11-2	10-5	9-7	8-5
	16"	11-11	11-3	10-6	9-8	8-6	10-9	10-2	9-6	8-9	7-4
	24"	10-5	9-10	9-2	8-5	6-11	9-5	8-11	8-4	7-8	6-0
2 x 6	12"	18-6	17-9	16-11	15-10	14-6	17-2	16-5	15-8	14-7	12-9
	16"	17-3	16-7	15-9	14-8	12-11	15-10	15-4	14-5	13-3	11-1
	24"	15-7	14-11	14-0	12-10	10-6	14-3	13-5	12-7	11-7	9-1
2 x 8	12"	23-5	22-5	21-4	20-0	18-5	21-7	20-9	19-9	18-6	17-0
	16"	21-9	20-11	19-10	18-8	17-2	20-1	19-4	18-4	17-3	15-0
	24"	19-8	18-10	17-11	16-10	14-4	18-2	17-5	16-7	15-7	12-4
2 x 10	12"	27-11	26-9	25-5	23-11	22-0	25-10	24-10	23-7	22-1	20-4
	16"	26-0	24-11	23-8	22-3	20-5	24-0	23-1	21-11	20-7	18-11
	24"	23-6	22-6	21-5	20-1	18-1	21-9	20-10	19-10	18-7	15-7

* 15 PSF live load + 7 PSF dead load.
** 15 PSF live load + 15 PSF dead load.

FOR RAFTERS DESIGNED ON BASIS OF F.H.A. MINIMUM PROPERTY STANDARDS
REQUIREMENTS: TOTAL DESIGN LOAD USED FOR BOTH STRESS AND DEFLECTION
DEFLECTION = 1/180 SPAN TO 15 FEET; 1" MAXIMUM IN LONGER RAFTERS

TABLE MAY BE USED FOR INLAND DOUGLAS FIR, GRAND FIR, WESTERN LARCH, AND WESTERN HEMLOCK

Although the study is quite small, the advantages of drying to a low moisture content are clearly indicated. A significant increase in yield for E-1.8 grade is shown with a decrease in the two lower E-grades, E-1.4 and E-1.0.

Progress is being made in gaining national recognition of machine grading. The Federal Housing Administration has published an engineering release concerning the Western Pine Association's Amended Supplement 3, Mechanical Stress-Rated Lumber. The American Lumber Standards Committee has accepted Supplement 3 with certain minor provisions which will be satisfied with the next printing of the grade rule. The Southern Pine Association has written a grade rule to govern machine graded lumber which is currently being considered by various authorities. Several national building code groups are considering this same grading supplement and their acceptance is expected in the near future.

Electro-Mechanical Stress-Rated lumber has been enthusiastically accepted during the initial and subsequent trial marketing efforts. Potlatch has sold over twenty cars of dimension lumber, representing almost a million board feet in different regions of the United States. Roof truss fabricators have been especially cognizant of the potential of EMSR lumber and have used a considerable amount of the footage sold for prefabricated trusses.

To summarize, machine grading is a new concept which can change the whole technique of stress grading dimension lumber. Machine grading is here today! Code approvals and regulating bodies acceptances have been or are being sought. Machine grading has traveled a long way in the past few years, but much work still needs to be done. This will take the effort of not one company or one association, but of a whole industry.