



Standard Practice for Assigning Allowable Properties for Mechanically Graded Lumber¹

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1. Scope

1.1 This practice covers the methodology of grade qualification, assignment of design properties, and requirements for the quality control of mechanically graded solid sawn lumber.

1.2 This practice acknowledges alternative methods for the assignment of specific properties. These methods are assignment by test, relationship to other properties, and by procedures in other appropriate standards.

2. Referenced Documents

2.1 ASTM Standards:²

- D9 Terminology Relating to Wood and Wood-Based Products
- D143 Test Methods for Small Clear Specimens of Timber
- D198 Test Methods of Static Tests of Lumber in Structural Sizes
- D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber
- D1165 Nomenclature of Commercial Hardwoods and Softwoods
- D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens
- D2395 Test Methods for Specific Gravity of Wood and Wood-Based Materials
- D2555 Practice for Establishing Clear Wood Strength Values
- D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
- D3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
- D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D4444 Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters

D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material

2.2 ANSI Standards:³

ANSI/AITC A190.1 American National Standard for Wood Products—Structural Glued Laminated Timber

ANSI/AF&PA NDS National Design Specification for Wood Construction

2.3 Canadian Standards Association Standard:⁴

CSA O141 Softwood Lumber

2.4 National Institute of Standards and Technology Standard:⁵

PS 20 Voluntary Product Standard, American Softwood Lumber Standard

3. Terminology

3.1 *Definitions*—For definitions of terms related to wood, refer to Terminology D9.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *mechanical evaluation, n*—identification and appraisal of one or more physical or mechanical lumber characteristics as part of the lumber segregation process.

3.2.2 *mechanically graded lumber, n*—solid sawn lumber graded by mechanical evaluation. Visual evaluation also may be required. The material has assigned design properties and is manufactured for use as structural members.

3.2.3 *qualified agency, n*—an organization, hereafter referred to as the agency, that has trained personnel and procedures to ensure the system evaluations and grades comply with all applicable requirements of this practice.

3.2.3.1 *Discussion*—The agency shall have no financial interest in, nor shall be financially dependent upon, any single company manufacturing the product being inspected or tested; and shall not be owned, operated, or controlled by any such company.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, <http://www.csa.ca>.

⁵ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

3.2.3.2 *Discussion*—The agency shall conform with the provisions for agency accreditation under the appropriate consensus standard.

3.2.4 *visual evaluation, n*—identification and appraisal of lumber growth and manufacturing characteristics by visual means as part of the lumber segregation process.

NOTE 1—In the United States and Canada, criteria for agency accreditation are contained in PS 20, ANSI/AITC A190.1, and CSA O141.

4. Significance and Use

4.1 The procedures described in this practice are intended to be used to establish appropriate allowable unit stresses, moduli of elasticity, and specific gravity for mechanically graded solid sawn lumber. An on-going quality control program to monitor compliance with the assigned grade properties is required.

5. System Requirements

5.1 *Mechanical Device Requirements* —A mechanical device used as part of the grading process shall demonstrate the ability to measure the mechanical or physical wood property used to segregate the lumber.

5.2 *Visual Requirements:*

5.2.1 Characteristics to be limited by visual evaluation, shall be documented as part of the qualification and quality control procedures. Such limitations shall be part of the grade requirements.

5.2.2 Personnel conducting visual evaluations shall be qualified by the agency.

6. Criteria for Grade Qualification

6.1 *General Requirements:*

6.1.1 A minimum of one assigned property of a grade shall be qualified by test. The grade assignment for properties qualified by test is given in 7.2.

6.1.1.1 If the modulus of elasticity (*MOE*) is the only property assigned to a grade, it shall be evaluated by test.

6.1.1.2 If both strength and *MOE* properties are assigned to a grade, a minimum of one strength property and one *MOE* property shall be evaluated by test. If only one strength property is tested, that property shall be either the modulus of rupture (*MOR*) or ultimate tensile stress (*UTS*).

6.1.2 Each grade shall be qualified at each size and for each species/species group.

6.1.3 Sampling, evaluation, and presentation of data shall be in accordance with Practice D2915.

6.2 *Qualification Samples:*

6.2.1 The criteria for selecting qualification samples shall be documented and shall be in accordance with 6.1.3.

6.2.2 All qualification samples shall meet the visual requirements established for the grade.

6.2.3 The minimum sample size for estimation of strength properties, and *MOE* shall be 53 specimens.

6.2.4 The minimum sample size for estimation of mean or median property values, other than *MOE*, shall be 30 specimens.

6.2.5 When the allowable shear stress parallel to grain (*F_v*) or the allowable compressive stress perpendicular to grain

(*F_{c⊥}*) are determined in accordance with 7.3.4 and 7.3.5, respectively, the specific gravity of a minimum of 30 qualification test specimens shall be measured and recorded.

6.3 *Qualification Test Methods:*

6.3.1 When mechanical and physical properties in Section 7 are determined by tests, the appropriate ASTM standards shall be used.

6.3.2 Mechanical test methods shall be in accordance with Test Methods D143, D198, or D4761.

6.3.2.1 The determination of the *MOE* and *MOR* by edge-wise bending shall employ third-point in accordance with Test Methods D4761.

6.3.2.2 The determination of the *MOE* by flat-wise bending shall be in accordance with Test Methods D4761.

6.3.2.3 The *UTS* of a sample shall be determined according to Test Methods D4761. Whenever possible, a minimum gage length of not less than 96 in. (2.44 m) shall be used. When determination of the tension parallel to the grain *MOE* is desired, testing shall be conducted according to the provisions of Test Methods D198.

6.3.2.4 The determination of the ultimate shear strength parallel to grain values shall be in accordance with Test Methods D143.

6.3.2.5 The determination of the compression perpendicular to grain values shall be in accordance with Test Methods D143.

6.3.3 Specific gravity shall be based on weight and dimensions when oven dry as specified in Test Methods D2395. Measurements shall either be taken on oven-dried specimens, or at some other moisture content and the values adjusted to the oven-dry condition.

6.3.4 Determination of the moisture content of the lumber sample shall be in accordance with Test Methods D4442 or D4444.

7. Procedures for Assignment of Allowable Mechanical Properties and Specific Gravity

7.1 Allowable mechanical properties and specific gravity shall be assigned using the qualification test procedures of 7.2, the property correlation procedures of 7.3, or the procedures of 7.4. These alternative procedures of 7.2-7.4 define the maximum property values, which are permitted to be assigned to a grade of mechanically graded lumber.

7.1.1 Selection of the procedures specified in 7.1 to establish a value for any particular property assigned to a grade is the prerogative of the grade specification author.

7.1.2 The factors used in 7.2 and 7.3 apply to softwood lumber.

7.1.3 If the *F_b* is to be an assigned property, it shall be determined by the test procedures of 7.2.

7.1.4 Hardwood lumber species shall be reduced by the applicable factors in Practice D245, Table 8.

7.1.4.1 Species containing interlocked grain shall have *F_b*, *F_t*, and *F_c* evaluated by test procedures of 7.2. Sample size selection shall consider the evidence of interlocked grain and its representation in the sample.

7.2 *Assignment of Allowable Properties by Qualification Tests:*

7.2.1 Assignment of allowable properties by test shall follow the procedures of this section. Test results shall be evaluated according to Practice **D2915**.

7.2.1.1 Qualification tests are used to either establish allowable mechanical property values for new grades or to qualify for published grade categories.

7.2.2 *Extreme Fiber Stress in Bending (F_b)*—The fifth percentile tolerance limit (75 % confidence) for the *MOR* of the qualification sample shall equal or exceed 2.1 times the assigned F_b value.

7.2.3 *Fiber Stress in Tension Parallel to Grain (F_t)*—The fifth percentile tolerance limit (75 % confidence) for the *UTS* of the qualification sample shall equal or exceed 2.1 times the assigned F_t value.

7.2.4 *Fiber Stress in Compression Parallel to Grain (F_c)*—The fifth percentile tolerance limit (75 % confidence) for ultimate compressive strength parallel to grain (*UCS*) of the qualification sample shall equal or exceed 1.9 times the assigned F_c value.

7.2.5 *Shear Stress Parallel to Grain (F_v)*—The fifth percentile tolerance limit (75 % confidence) F_v for the qualification sample shall equal or exceed 2.1 times the assigned F_v value.

7.2.6 *Modulus of Elasticity*—The upper 95 % confidence interval of the qualification sample mean *MOE* shall equal or exceed the assigned grade *MOE*.

7.2.6.1 The upper bound of the 95 % confidence interval of the qualification sample mean *MOE* shall meet or exceed the assigned grade *MOE*.

7.2.6.2 For grades that include a near-minimum *MOE* specification, the sample parametric or non-parametric point estimate as determined in accordance with Practice **D2915** shall equal or exceed the near-minimum *MOE* for the grade.

7.2.7 *Specific Gravity (SG)*—The upper bound of the 95 % confidence interval of the qualification sample mean specific gravity shall meet or exceed the assigned specific gravity value.

7.2.8 *Fiber Stress in Compression Perpendicular to Grain ($F_{c\perp}$)*—The $F_{c\perp}$ shall be determined by test in accordance with Test Methods **D143**, and adjusted by the procedures of Practice **D245**.

7.3 *Assignment of Allowable Properties Based on Relationships:*

7.3.1 The methods of 7.3 permit assignment of certain allowable properties based on recognized relationships between the assigned properties. This assignment shall be in accordance with the following procedures.

7.3.2 *Fiber Stress in Tension Parallel to Grain:*

7.3.2.1 The maximum allowable F_t shall be assigned in accordance with an established grade assignment model based on the assigned F_b , which has been published by the agency.

7.3.2.2 In the absence of corroborative data, a maximum F_t/F_b ratio of 0.45 shall be used.

7.3.3 *Fiber Stress in Compression Parallel to Grain:*

7.3.3.1 The maximum allowable F_c shall be calculated from the following equation:

$$F_c = (0.7098F_b + 2060.7)/1.9 \quad (1)$$

where:

F_b = the assigned F_b for the grade.

7.3.4 *Shear Parallel to Grain*—The F_v determined by a specific gravity-based model (see **Appendix X1**) is permitted when the specific gravity is assigned in accordance with 7.2.7 or 7.3.6.

7.3.5 *Fiber Stress in Compression Perpendicular to Grain ($F_{c\perp}$)*—The $F_{c\perp}$ determined by a specific gravity-based model (see **Appendix X1**) is permitted when specific gravity is assigned in accordance with 7.2.7 or 7.3.6.

7.3.6 *Specific Gravity*—It is permitted to assign specific gravity in accordance with a model that relates grading machine measurement to specific gravity. When such a model is used, the agency shall develop corroborative data to support the appropriateness of the assigned specific gravity.

7.4 *Assignment of Allowable Properties by Other Standards:*

7.4.1 The methods of 7.4 permit assignment of certain allowable properties based on procedures in the appropriate ASTM and ANSI standards.

7.4.2 *Shear Parallel to Grain Stress*—The F_v shall be assigned in accordance with the procedures of Practice **D245** for visually graded solid sawn lumber of the same species or species group.

7.4.3 *Fiber Stress in Compression Perpendicular to Grain*—The $F_{c\perp}$ shall be assigned in accordance with the procedures of Practice **D245** for visually graded solid sawn lumber of the same species or species group.

7.4.4 *Specific Gravity*—The specific gravity shall be assigned as reported in ANSI/AF&PA NDS for visually graded solid sawn lumber of the same species or species group.

8. Minimum Allowable Property Increment

8.1 Allowable properties shall be rounded in accordance with **Table 1**.

9. Quality Control

9.1 A quality control program shall be developed for each mechanical grading system. The quality control program shall delineate the respective responsibilities of the producer and the agency.

9.2 The quality control program shall include monitoring and control of both the mechanical and visual portions of the system.

9.2.1 The visual evaluation of the grade shall be conducted in accordance with the applicable agency requirements.

9.2.2 The quality control program shall address the procedures for quality control of the mechanical system.

TABLE 1 Rounding Rules for Allowable Property Values

MOE	100 000 psi
F_b	50 psi at 1000 psi and above
	25 psi below 1000 psi
F_t	25 psi
F_c	25 psi
$F_{c\perp}$	5 psi
F_v	5 psi
SG	0.01

9.3 The quality control program shall require periodic evaluation of at least one of the assigned properties qualified in 6.1.1.

9.4 A quality manual shall be prepared for each production facility.

9.4.1 The quality manual shall address precision and bias of calibration and measurement.

9.4.2 The manual shall describe the inspection, sampling, testing, and analysis to be conducted in accordance with this practice and other applicable requirements.

9.4.3 The manual shall describe corrective action to be taken with nonconforming material.

9.4.4 Documentation requirements of the quality control program shall be described in the manual, including retention and other applicable requirements.

9.4.5 The manual shall describe the individual and joint responsibilities of the production facility and the agency.

10. Keywords

10.1 lumber; mechanically graded lumber; solid sawn lumber; wood

APPENDIXES

(Nonmandatory Information)

X1. FORMULAS FOR DETERMINING THE SHEAR STRESS PARALLEL TO GRAIN AND FIBER STRESS IN COMPRESSION PERPENDICULAR TO GRAIN

X1.1 Shear Stress Parallel to Grain

X1.1.1 When qualified by measurement of the specific gravity (SG), the allowable stress in shear stress parallel to the grain (F_v) shall be calculated by a relationship between SG (based on oven dry weight/oven dry volume basis) and F_v :

X1.1.2 For Douglas Fir, Douglas Fir-Larch, Douglas Fir-South, Hem-Fir, Southern Pine, Spruce-Pine-Fir (South), Western Woods, and Western Cedars:

$$F_v = (266 \times SG) + 40 \quad (X1.1)$$

X1.1.3 For Douglas Fir-Larch (N), Hem-Fir (N), and Spruce-Pine-Fir:

$$F_v = (284.8 \times SG) + 26.6 \quad (X1.2)$$

where:

SG = specific gravity (oven-dry weight/oven-dry volume basis)

X1.2 Compression Perpendicular to the Grain ($F_{c\perp}$) (0.04-in. deformation limit)

X1.2.1 When qualified by measurement of the SG , the allowable stress shall be calculated by a relationship between SG (based on oven dry weight/oven dry volume) and $F_{c\perp}$:

X1.2.1.1 For Douglas Fir, Douglas Fir-Larch, Douglas Fir-South, Hem-Fir, Southern Pine, Spruce-Pine-Fir (South), Western Woods, and Western Cedars:

$$F_{c\perp} = (2252.4 \times SG) - 480 \quad (X1.3)$$

X1.2.1.2 For Douglas Fir-Larch (N), Hem-Fir (N), and Spruce-Pine-Fir:

$$F_{c\perp} = (2243.8 \times SG) - 473.8 \quad (X1.4)$$

X1.3 Compression Perpendicular to the Grain ($F_{c\perp}$) (0.02-in. deformation limit)

X1.3.1 Refer to the appropriate agency grading rules for equations to adjust the $F_{c\perp}$ from a 0.04-in. deformation limit to a 0.02-in. deformation limit.

X2. EXPLANATION OF SOLID SAWN LUMBER PRODUCTS CURRENTLY PRODUCED IN THE UNITED STATES AND CANADA BY NONDESTRUCTIVE EVALUATION

X2.1 Mechanically Graded Lumber

X2.1.1 *General*—The process where each piece of lumber is nondestructively evaluated by a machine to determine the value of the sorting parameter or grading algorithm. Mechanically graded lumber also is required to meet certain visual requirements. The process assigns strength and *MOE* values based on a model that combines information from the nondestructive parameter and visual characteristics. One exception is *E*-rated lumber; strength values are not assigned to *E*-rated lumber.

X2.2 Machine Stress-Rated Lumber

X2.2.1 Lumber sorted by machine and graded based on the following criteria, established under the ALSC PS 20:

X2.2.1.1 Average edge *MOE* equal to or greater than the assigned average edge *MOE*.

X2.2.1.2 At least 95 % of pieces have an edge *MOE* greater than 82 % of the assigned edge *MOE*.

X2.2.1.3 At least 95 % of the pieces have a *MOR* greater than 2.1 times the assigned *Fb*.

X2.3 Machine Evaluated Lumber

X2.3.1 Machine evaluated lumber is sorted by machine and graded based on the following criteria, established under the ALSC PS 20:

X2.3.1.1 Average edge *MOE* equal to or greater than the assigned average edge *MOE*.

X2.3.1.2 At least 95 % of pieces have an edge *MOE* greater than 75 % of the assigned edge *MOE*.

X2.3.1.3 At least 95 % of the pieces have a *MOR* greater than 2.1 times the assigned *Fb*.

X2.3.1.4 At least 95 % of the pieces have a *UTS* greater than 2.1 times the assigned *Ft*.

X2.4 *E*-Rated Lumber

X2.4.1 *E*-rated lumber is graded by mechanical grading into specific *MOE* categories. The process assigns a long-span flat-wise *MOE* value and requires adherence to a fifth percentile *MOE* value. Practice **D3737**, Annex A2, specifies the relationship between the mean and fifth percentile *MOE* values:

$$MOE_{5th} = 0.955 MOE_{mean} - 0.233 \quad (X2.1)$$

X3. TRADITIONAL VISUAL GRADING REQUIREMENTS FOR MECHANICALLY GRADED LUMBER PRODUCED IN THE UNITED STATES AND CANADA

X3.1 Introduction

X3.1.1 Mechanically graded lumber has traditionally been, and is currently, a performance-based product. Prior to 1990, a common set of visual limitations was widely utilized in the United States and Canada. These limitations had been developed to enhance sorting efficiency. Since 1990, some of the regional grading agencies have developed alternate visual limitations keyed more closely to the performance and growth characteristics of the species or species grouping involved. This portion of the appendix is presented to document the historical baseline requirements for these visual characteristics.

X3.2 Some grade rules for machine stress rated (*MSR*) lumber have traditionally limited edge characteristics as follows:

X3.2.1 Knots, knot holes, burls, distorted grain, or decay partially or wholly at edges of wide faces must not occupy more of the net cross section than:

- 1/6 — ≥2100 *Fb*
- 1/4 — 1500 *Fb* to 2050 *Fb*
- 1/3 — 1000 *Fb* to 1450 *Fb*
- 1/2 — ≤1000 *Fb*

X3.3 Grade rules for *E*-rated lumber have traditionally limited edge characteristics similar to *MSR*, however, at an *MOE* level, more than one edge characteristic value is permitted, each one forming a separate grade. For example, at an *MOE* level of 2.3, one grade may be 2.3-1/6 (an edge charac-

teristic 1/6 th of the cross section is permitted) while a second grade may be 2.3-1/2 (a 1/2 cross section characteristic is permitted).

X3.4 Some grade rules for *MSR* and *E*-rated lumber have traditionally limited edge characteristics and slope of grain in areas of the piece not mechanically graded as follows:

X3.4.1 *Edge Characteristics*—Limited as listed in **X3.2**.

X3.4.2 *Non-Edge Knots*—Equal to the largest non-edge knot in the tested portion of the piece or the next larger edge characteristics, whichever is greater. For 1/2 edge characteristics categories, non-edge knot limited to 2/3 cross section.

X3.4.3 *Slope of Grain*—The general slope of grain shall not exceed:

Slope	<i>Fb</i> Class
1 in 12	≥2100
1 in 10	1500 to 2050
1 in 8	1050 to 1450
1 in 4	≤1000

X3.5 Some visual criteria have been required of mechanically graded lumber to assure specific market utilization. One example is that *E*-rated grades must meet surfacing and other laminating requirements. Visual “over-rides” equivalent to some visual grades commonly are required of mechanically graded lumber. While these visual criteria are usually not linked directly to mechanical performance criteria, as in **X3.2** and **X3.4**, their existence affects selection of samples for



performance tests and influences grade yields.

X4. COMMENTARY

TABLE X4.1

Section	Comments
3.2.1	<p>Mechanically graded lumber is the generic terminology adopted by the committee to encompass grading systems that incorporate the methods described in 3.2.2. In the first years of mechanical grading in and in some contemporary systems outside of the United States and Canada, little or no visual evaluation is incorporated in the system. In the United States (U.S.) and Canada at the time of the origin of this practice, all commercial methods incorporated both mechanical (or physical) and visual evaluations.</p> <p>Historically, the terminology used with mechanical grading, such as <i>EMSR</i>, <i>MSR</i>, and <i>E</i>-rated, referred to the process of grading. In 1996, the American Lumber Standard Committee (ASLC) adopted a different procedure in which the nomenclature reflected the qualification requirements rather than the process. Consequently, at the time of the origin of this standard, there are three types of grading systems, machine stress rated (<i>MSR</i>), machine evaluated lumber (<i>MEL</i>), and <i>E</i>-rated, all defined by the testing requirements. These definitions are included in Appendix X2. It is with the background in these systems and their evaluation that this standard has been prepared. <i>EMSR</i> denotes electromechanical stress rated lumber graded with the continuous lumber tester.</p>
3.2.3	<p>Agency responsibilities are emphasized in this practice. Decisions such as final requirements for qualification and quality control, based on this practice, are to be made by the agency. To ensure that the agency is qualified for these responsibilities, this practice requires accreditation under recognized consensus standard procedures.</p>
3.2.4	<p>The sense of the committee is that optical detection systems are intended to be included in this section.</p>
4.1	<p>Presently in the U.S. and Canada, mechanical grading is applied to dimension lumber only. The grading equipment measures one physical or mechanical property (such as flexural stiffness or density), which, along with visual characteristics, is used to establish allowable properties. Some allowable properties are developed by relationship to the measured property.</p>
5.1	<p>Presently in the U.S. and Canada, the ALSC and the Canadian Lumber Standards Accreditation Board (CLSAB) have established criteria for appraisal and approval of the performance of equipment for mechanical lumber grading. The performance characteristics of <i>E</i>-rated lumber are specified under ANSI/AITC A190.1.</p>
5.2.1	<p>In U.S. and Canadian practice, characteristics are limited by grade level and location in the piece, see Appendix X3. The provisions of this section are not intended to apply to those visual over-rides that are applied on a customer-specific basis for market acceptance reasons, as discussed in Appendix X3.</p>
5.2.2	<p>In the U.S. and Canada, qualification of personnel for visual evaluation of mechanically graded lumber has been conducted under the auspices of PS 20, ANSI/AITC A190.1, and CSA O141.</p>
6.1.1	<p>Some mechanical grades, such as <i>E</i>-rated lumber may claim only one allowable property; consequently, 6.1.1.1 requires that property be evaluated in qualification.</p> <p>Some mechanical grades may claim more than one strength property and modulus of elasticity. Paragraph 6.1.1.2 requires that at least one strength and one modulus be evaluated. This does not imply that more cannot be required by the agency. Experience with performance of species/grade/sizes in qualification and quality control tests provides guidance to the agency. It is the intent of 6.1.1 that the final requirements for qualification are the responsibility of the agency.</p> <p>Please see commentary under 7.3.1 for additional information regarding qualification requirements.</p>
6.1.1.2	<p>The <i>MOE</i> selection relates to end use. See 6.3 for <i>MOE</i> qualification requirements</p>
6.1.2	<p>This practice recognizes that properties have been assigned by traditional relationships between allowable properties and measured variables or other allowable properties. An example for over 20 years was the relationship between F_c and F_b (recently changed). While the choice of this relationship approach must be acceptable to both the producer (for marketing reasons) and the agency (for technical reasons), adherence to this practice and that of the agency is required. Again, reference to the commentary under 7.3.1 may be appropriate.</p> <p>It is important to make sure that sampling is conducted in a way that reflects the condition when more than one grade is pulled at a time from the same population. An example of this would be when one grade with a ¼ edge characteristic limit, as defined in Appendix X3, and another grade with a ½ edge characteristic limit are produced at the same time.</p> <p>North American commercial species groups are listed in Nomenclature D1165 and PS 20.</p>
6.1.3	<p>This is a traditional requirement. Accumulated data on size and grade effects continues to support the appropriateness of this requirement. It is not the intent of the committee to limit analysis and presentation to the methods of Practice D2915. More extensive methods are encouraged where appropriate and documented.</p>
6.2.3	<p>This requirement is based on the need to estimate the fifth percentile of a population from a sample. In accordance with Practice D2915, the point estimate (<i>PE</i>) or the tolerance limit (<i>TL</i>) are used; often, the 5 % nonparametric <i>TL</i> (with 75 % confidence). The <i>PE</i> is required for flat-wise <i>MOE</i> of <i>E</i>-rated lumber and the <i>TL</i> for tensile, bending, and compression parallel strength properties. Samples larger than the minimum specified in 6.2 are recommended for a more substantial data base because, while a sample of 53 specimens meets the requirements of this standard, the information obtained from minimal sample sizes is restricted. A larger sample may provide more representative data and a better base for subsequent quality control.</p>
6.2.4	<p>This requirement comes into effect only where no near-minimum requirement exists. Further, since confidence intervals are used to judge adequacy of the mean <i>MOE</i>, a larger sample may enhance the analysis as well as provide a better database for future use.</p>



TABLE X4.1 Continued

Section	Comments
6.2.5	Please see 6.2.3 and 6.2.4. Shear parallel to grain also is referred to as horizontal shear.
6.3.2	This requirement standardizes the measurement and adjustment process so that subsequent adjustments may be made if needed. Other ASTM standards are important adjunct test methods even if the primary goal is a mechanical test. It is recommended that ASTM standards be used to determine specific gravity and moisture content even if these are not property establishment.
6.3.2.1	The past practice of some agencies edge bending test procedures included the random placement of the maximum edge defect with respect to the tension or compression edge. For MOR testing, the maximum edge defect is placed in the middle third of the testing span, whenever possible.
6.3.2.3	In the U.S. and Canada, agencies often specify the maximum edge defect be located in the gage length whenever possible.
6.3.2.4 and 6.3.2.5	The traditional method of assigning Fv has been through test values determined from clear, straight grain wood using Test Methods D143. Consequently, virtually all current wood design values in North America are based on this method.
7.1	In the U.S. and Canada, the grade specifications for mechanically graded lumber are customarily authored by one or more of the regional grading agencies accredited by the ALSC and CLSAB, or agencies qualified under ANSI/AITC A190.1.

In the U.S. and Canada, usually six properties are assigned to mechanically graded lumber. These properties are assigned by qualification test, property relationship, or by optional assignment. Traditionally, the assignment of properties is as follows:

Property Assignment Procedure	Traditional Procedures for the Assignment of MGL Property Values					
	Fb	Ft	Fc	Fv	Fc⊥	MOE
Property Test	Test or Optional Assignment	Property Relationship	Test or Property Relationship	Test or Property Relationship	Test or Property Relationship	Test

Traditionally, the SG for mechanically graded lumber was based on the species-specific assignment developed using Test Methods D2555 and published in the ANSI/AF&PA NDS. In the 1990s, the ALSC adopted a program for the assignment of a grade-specific SG for certain MGL grades where the SG qualified by test and monitored as part of a quality control program.

Prior to 1996, when the long-span modulus of elasticity (LS MOE) for mechanically graded lumber was assigned, such as for E-rated lumber, the lumber had to be qualified by test. In 1996, ALSC recognized the relationship between the edge MOE and the LS MOE.

Contemporary Optional Procedures for the Assignment of MGL Property Values		
Property Assignment Procedure	SG	LS MOE
Property Test or Optional Assignment	Test or Optional Assignment	Test or Property Relationship

- 7.1.4.1 Research shows that the relationship between MOR, UTS, and UCS for most hardwood species follow relationships similar to those for softwood species, and that domestic hardwoods can be mechanically graded by procedures traditionally used with softwoods (1)^A. However, a few temperate hardwood species and a number of tropical hardwoods, contain interlocked grain (also called double spiral grain). Some domestic species that commonly contain interlocked grain include Tupelo, Blackgum, Sweetgum, Sycamore, Cottonwood, and the Elms. There is a limited amount of data on 2 by 4's for a tropical species containing interlocked grain that indicates the relationship between MOR and UTS is similar to that of softwood species and hardwood species without interlocked grain; however, the data also indicated that the relationship between MOR and UCS may not be the same as that assumed for softwoods (1). Until additional data are available for hardwoods with interlocked grain, this practice requires that the Fb, Ft, Fc, and MOE values be qualified by test in accordance with 7.2.
- 7.2 Assignment requirements in this section are traditional bases for establishing allowable properties for mechanical grades by test. The reduction factors incorporated in the requirements are adopted from Practice D245.
- 7.2.1.1 The distinctions in this section between two objectives is to clarify that the procedures of this standard apply to both. Other criteria not part of this standard, such as sampling and special analysis considerations for implementation, also may apply and may differ according to objective. Presently, there are no approved small clear ASTM test methods for pieces less than 2 in. in thickness for C⊥ and Fv; therefore, these properties are not addressed at this time.
- 7.2.2 Prior to the adoption of this standard, the PE commonly was used in determining the MOR.
- 7.2.6 This section emphasizes that the goal is to estimate the mean of the target population from a small and finite sample. This estimated mean is required to not significantly differ from the grade MOE. One method is to calculate a confidence interval about the mean estimate for comparison of the sample to the grade requirement. This section interacts with the sample size requirements of 6.2. In the U.S. and Canada, some agencies specify a near minimum (lower quantile) qualification requirement for MOE.
- 7.2.6.2 Most mechanically graded solid sawn lumber in North America undergo daily off-line quality control tests where the average and lower fifth percentile point estimate of the process is monitored and compared with the grade MOE specifications. Although both strength properties and the near-minimum MOE are set at the lower fifth percentile point estimate, it is not necessary to require that the strength and near-minimum MOE be estimated at the same level of confidence. In the case of the mean MOE, it is only necessary to demonstrate that the sample results are not significantly different from the grade MOE. However, due to the difficulty in estimating reasonable confidence intervals for near-minimum values using the minimum sample sizes specified in this practice, it was judged to be acceptable and consistent to use the point-estimate statistics as determined in accordance with Practice D2915. Near-minimum or limiting variability grade requirements are found in grade specifications, such as grading rules approved by the American Lumber Standard, American National Standards Institute, Canadian Standards Association, and design properties listed in the National Design Specification for Wood Construction.
- 7.2.7 Please see 7.2.6 discussion on confidence intervals.

TABLE X4.1 *Continued*

Section	Comments
7.3.1	<p><i>General</i>—When <i>MSR</i> was developed, the allowable tensile stresses were assigned to equal the allowable bending stresses (2). After a short time, the procedure was changed to set the allowable tension stress at 80 % of the allowable bending stress. Somewhat later, a graduated scale was developed in which a value of 80 % was assigned at high levels, and incrementally scaled down to a minimum 50 % at low levels. This has been the standard procedure for some 25 years. “Standard,” in this case, means where the assignment is based on test of E_e and F_b only.</p> <p><i>Width Effect</i>—It is important to note that much of the above history and the test observations made in the first 20+ years of <i>MSR</i> were based on 2 by 4. Further, it was difficult to conduct a full-size tensile test outside of a research laboratory until the early 1980s because of the development history of test equipment (2). In the '80's, test data on more grades and widths of <i>MSR</i> began to accumulate. The result was recognition that width effects in <i>MSR</i> lumber are very similar to those recognized in visually graded lumber (2,3). The difference is that the <i>MSR</i> system can adapt to the width effect and “hold” the same strength properties by adjusting the selection criteria, for example, E. As an example, a current Douglas Fir grade in 2 by 4 may require a 2.2 average E_e to make a 1925 F_t assignment while, 2 by 6, may require an E_e of 2.4 million psi for the same F_t.</p> <p>The impact of accommodating the width effect in lumber grades interacts with marketing of the grades. A common solution is to ignore the width effect to simplify marketing; in this scenario, the grade in the above example would be marketed with the same F_t and E_e, even though test and QC data would support a higher value of E for the 2 by 6.</p>
7.3.2.1	<p><i>Tension/Bending Ratios</i>—As more experience (data) has developed with the advent of tensile and bending tests of <i>MSR</i> grades, the question of the appropriate tensile/bending ratios has reopened. The early observations referred to above often were based on samples of limited size and grades and, necessarily, on inferences to be applied to a number of species/grade combinations. As more data developed, methods of data analysis also improved, and as noted above, the adherence to a strict set of “standard” grade properties changed. Some analysis have now shown that the “standard” of 80 % ≥ 50 % of F_b for assignment of F_t may not be correct for some species/grades. A high value of about 70 % appears more optimal, while a value of 55–60 % appears more correct for some grades with a $\frac{1}{8}$-edge knot.</p> <p>These observations have several potential impacts. For marketing efficiency, it may be desirable to restrain the proliferation of grade property combinations. To do this, however, requires verification by test that the values assigned by “standard” or other non-test procedures are adequate. This is critical from two aspects. If only F_b is checked in qualification, and a “too high” ratio is used to set F_t, this F_t may not be verifiable by test. If, on the other hand, qualification is carried out by F_t, and the ratio used is “too low,” the calculated F_b may be higher than can be verified by test. The conclusion is that a corroboration of both F_t and F_b is desirable.</p>
7.3.2.2	The default ratio of 0.45 for F_t/F_b is based on Practice D1990 and agency test observations.
7.3.3.1	<p><i>Compression Parallel to Grain</i>—The previous discussion has dealt only with the relationship between E_e, F_b, and F_t. F_c also is of interest. Traditionally, this property had a higher ratio to F_b than the visual grades.</p> <p>F_c was evaluated thoroughly for visual grades in the North American In-Grade Lumber Testing Program (4). Subsequently, tests of four <i>MSR</i> grades at Washington State University were analyzed using the analytical method developed in the in-grade program. These tests verified a new F_c/F_b relationship for <i>MSR</i> that is now used in the American Lumber Standard Committee-approved rules.</p>
7.3.6	The intent of this section is to recognize the specific gravity predictive relationships that may be established by agencies with the machine measurement variable(s). Corroborative data in support of the model used in 7.3.6 may include qualification and quality control data developed in accordance with the requirements of 7.2.6, 7.2.7, and Section 9.
7.4	These relationships are traditional. Some are based on a clear wood data base of species or species groups. The values determined by this section may differ from those of 7.3; however, the relevance of the property to end uses and traditional applications may be important in determining use of 7.4.
8	These increments are consistent with other ASTM standards.
9	This section emphasizes that, while Sections 6-8 of the standard “set-the-stage” for production through qualification procedures, a comprehensive and responsible grading system relies on the follow through of a quality control system and agency monitoring.

^A The boldface numbers in parentheses refer to the list of references at the end of this standard

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