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Standard Specification for Computing Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design[1]

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INTRODUCTION

Load and resistance factor design (LRFD) is a structural design method that uses concepts from reliability theory and incorporates them into a procedure usable by the design community. The basic design equation requires establishing a reference resistance based on several material property parameters. A standard method for calculating the required material property input data is critical so that all wood-based structural materials can be treated equitably. This specification provides the procedures that are required for the generation of reference resistance for LRFD.

1. Scope

1.1 This specification covers procedures for computing the reference resistance of wood-based materials and structural connections for use in load and resistance factor design (LRFD). The format conversion procedure is outlined in Section 4. The test-based derivation procedure is outlined in Annex A1. The reference resistance derived from this specification applies to the design of structures addressed by the load combinations in ASCE 7-16.

1.2 A commentary to this specification is provided in Appendix X1.

1.3 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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
D1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials
D1761 Test Methods for Mechanical Fasteners in Wood
D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens
D2718 Test Methods for Structural Panels in Planar Shear (Rolling Shear)
D2719 Test Methods for Structural Panels in Shear Through-the-Thickness
D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
D3043 Test Methods for Structural Panels in Flexure
D3500 Test Methods for Structural Panels in Tension
D3501 Test Methods for Wood-Based Structural Panels in Compression

[1] This specification is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.02 on Lumber and Engineered Wood Products.

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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.

D3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
D4761 Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Materials
D5055 Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists
D5456 Specification for Evaluation of Structural Composite Lumber Products
E105 Practice for Probability Sampling of Materials

2.2 *ASCE Standard:*[3]
ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures

3. Terminology

3.1 *Definitions:*

3.1.1 For general definitions of terms related to wood, refer to Terminology D9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ASD reference design value, F_x*—the design value at reference conditions used in allowable stress design (ASD) prior to application of the load duration factor (C_D).

3.2.2 *coefficient of variation, CV_w*—a relative measure of variability based on the shape parameter of the 2-parameter Weibull distribution.

3.2.2.1 *Discussion*—It is not the traditional sample standard deviation of the data divided by the sample mean.

3.2.3 *data confidence factor, Ω*—a factor that is used to adjust member reference resistance for sample variability and sample size.

3.2.4 *distribution percentile, R_p*—the value of the distribution associated with proportion, p, of the cumulative distribution function.

3.2.5 *factored resistance*—the product of the resistance factor (ϕ) and the reference or nominal resistance (R_n).

3.2.6 *format conversion factor, K_F*—a factor applied to convert resistance from the allowable stress design (ASD) format to the LRFD format, equal to the ratio R_n / F_x.

3.2.7 *lower tail*—a portion of an ordered data set consisting of all test specimens with the lowest property values (for example, lowest strengths).

3.2.8 *nominal resistance*—a term equivalent to the reference resistance used in reliability analysis and LRFD standards.

3.2.9 *reference conditions*—the design basis for which all applicable adjustment factors are equal to unity, except for the load duration factor in ASD or the time effect factor in LRFD.

3.2.10 *reference resistance, R_n*—the design value at reference conditions used in LRFD to represent member resistance prior to application of the resistance factor (ϕ) and the time effect factor (λ).

3.2.10.1 *Discussion*—The reference value represents member resistance at 10-minute load duration.

3.2.11 *reliability normalization factor, K_R*—a factor used to establish the reference resistance (R_n) to achieve a target reliability index for a specific set of conditions.

3.2.12 *resistance factor, ϕ*—a factor applied to the resistance side of the LRFD equation.

4. Reference Resistance for LRFD

4.1 Reference resistance for LRFD shall be determined using one of the following procedures:

4.1.1 Format conversion per Section 4.2; or

4.1.2 Test-based derivation per Annex A1.

4.2 *Format Conversion Procedure:*

4.2.1 Resistance values for LRFD are permitted to be based on format conversion from code-recognized allowable stress design (ASD). It shall not be claimed that reference resistance values generated in this manner achieve a stated reliability index. Resistance factors for determining LRFD factored resistance, ϕR_n, are given in Table 1.

NOTE 1—Examples of standards that are used to generate code-recognized ASD values include Test Methods D143, D198, D1037, D1761, D2718, D2719, D3043, D3500, D3501, and D4761; Practices D1990 and D3737; and Specifications D5055 and D5456.

4.2.2 For standardization purposes, format conversion reference resistance values shall be based on the arithmetic conversion for a specific design case that results from the calibration of basic ASD and LRFD equations. Here, the calibration means providing an identical required section modulus, cross-sectional area, allowable load capacity, and so forth. The specific design case was chosen such that changes in design capacity over the range of expected load cases and load ratios were minimized.

4.2.3 Values of the format conversion factor, K_F, are given in Table 2.

4.2.4 The format conversion reference resistance is computed by multiplying the ASD resistance by K_F. For members and connections, the ASD resistance is based on a normal (10-year) load duration. For shear walls and diaphragms, the ASD resistance is based on a 10-minute load duration.

4.2.5 For lateral buckling (stability), compression perpendicular to grain, and rolling shear that is not subject to load duration or time effect adjustments, the value of K_F is based on the assumption that neither the ASD nor LRFD resistance values are modified by duration of load or time effect adjustments.

4.2.6 *Format Conversion Example*—An ASD bolt design value for a single shear connection, F_x, is 800 lbf (3.56 kN) (based on normal 10-year load duration). From Table 2, the

TABLE 1 Specified LRFD Resistance Factors, ϕ_s

Application	Property	ϕ_s
Members	compression[A]	0.90
	bending, lateral buckling (stability)	0.85
	tension parallel	0.80
	shear, radial tension	0.75
Connections	all	0.65
Shear Walls, diaphragms	shear	0.80

[A] Compression parallel-to-grain, compression perpendicular-to-grain, and bearing.

[3] Available from The American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191.

TABLE 2 Format Conversion Factor, K_F

Property	K_F
Compression Parallel to Grain	2.40
Bending	2.54
Tension Parallel to Grain	2.70
Shear	2.88[A]
Radial Tension	2.88
Connections	3.32
Lateral Buckling (Stability)	1.76
Compression Perpendicular to Grain	1.67
Shear Wall and Diaphragm Shear	2.00[B]

[A] The value of the format conversion factor is 2.00 where shear is not subject to load duration or time effect adjustments (e.g., rolling shear in cross-laminated timber).

[B] The format conversion factor for shear wall and diaphragm shear is only intended to be applied to the design capacity of shear wall or diaphragm assemblies, not to the design of individual members or subcomponents of these assemblies.

format conversion factor, K_F, is 3.32. The corresponding LRFD bolt reference resistance value is as follows:

$$R_n = K_F \times F_x = 3.32 \times 800 = 2658 \text{ lbf } (11.82 \text{ kN}) \quad (1)$$

4.2.7 *Format Conversion Example for Shear Walls or Diaphragms*—An ASD shear wall design value, F_x, is 395 lb/ft (5.76 kN/m) (based on a 10-minute load duration). From Table 2, the format conversion factor, K_F, is 2.00. The corresponding LRFD shear wall reference resistance value is as follows:

$$R_n = K_F \times F_x = 2.00 \times 395 = 790 \text{ lb/ft } (11.53 \text{ kN/m}) \quad (2)$$

5. Keywords

5.1 format conversion; load and resistance factor design (LRFD); reference resistance; structural connections; test-based derivation; wood-based materials

ANNEX

(Mandatory Information)

A1. TEST-BASED DERIVATION OF REFERENCE RESISTANCE FOR LRFD

A1.1 Parameters required for the derivation of reference resistance are presented in this Annex. These parameters include the distribution percentile, R_p, coefficient of variation, CV_w, data confidence factor, Ω, and reliability normalization factor, K_R. An example derivation of reference resistance is provided in X1.8.5.

A1.2 *Sampling*:

A1.2.1 Samples selected for analysis and implementation with this specification shall be representative of the population about which inferences are to be made. Both manufacturing and material source variability shall be considered. The principles of Practice E105 shall be maintained. Practice D2915 provides methods for establishing a sampling plan. Special attention is directed to sampling procedures in which the variability is low and results can be influenced significantly by manufacturing variables. It is essential that the sampling plan addresses the relative magnitude of the sources of variability.

A1.2.1.1 Data generated from a quality control program shall be acceptable if the criteria of A1.2.1 are maintained.

A1.2.1.2 *Multiple Data Sets*—When data from multiple data sets are compiled or grouped, the criteria used to group such data shall be in accordance with the provisions of A1.2.1. When such procedures are available in applicable product standards, they shall be used.

A1.2.2 *Sample Size:*

A1.2.2.1 For data sets in which all specimens are tested to failure, the minimum sample size shall be 30.

NOTE A1.1—The confidence with which population properties can be estimated decreases with decreasing sample size. For sample sizes less than 60, extreme care must be taken during sampling to ensure a representative sample.

A1.2.2.2 For lower tail data sets, a minimum of 60 failed observations is required for sample sizes of $n = 600$ or less. This represents at least the lower 10 % of the distribution. For sample sizes greater than 600, a minimum of the lowest 10 % of the distribution is required. For example, sample size, $n = 720$, 0.10 (720) = 72 failed test specimens in the lower tail. Only parameter estimation procedures designed specifically for lower tail data sets shall be used (see Appendix X2).

A1.3 *Testing*:

A1.3.1 Testing shall be conducted in accordance with appropriate standard testing procedures. The intent of the testing shall be to develop data that represent the capacity of the product under standard conditions.

A1.3.2 *Periodic Property Assessment*—Periodic testing is recommended to verify that the properties of production material remain representative of published properties.

A1.4 *Reference Resistance, R_n*—The following equation establishes reference resistance for LRFD:

$$R_n = R_p \times \Omega \times K_R \quad (A1.1)$$

where:

R_p = distribution percentile estimate,
Ω = data confidence factor, and
K_R = reliability normalization factor.

A1.4.1 *Distribution Percentile Estimate, R_p:*

A1.4.2 Eq A1.2 is intended to be used to calculate any percentile of a two-parameter Weibull distribution. The percentile of interest depends on the property being estimated.

$$R_p = \eta[-\ln(1 - p)]^{1/\alpha} \quad (A1.2)$$

where:

η = Weibull scale parameter,
p = percentile of interest expressed as a decimal (for example, 0.05), and
α = Weibull shape parameter.

A1.4.3 The shape (α) and scale (η) parameters of the two-parameter Weibull distribution shall be established to define the distribution of the material resistance (**1**).[4] Algorithms for common estimation procedures are provided in Appendix X2.

A1.4.4 *Coefficient of Variation, CV_w*—The coefficient of variation of the material is necessary when determining the data confidence factor, Ω, and the reliability normalization factor, K_R. The CV_w can be estimated from the shape parameter of the Weibull distribution as follows:

$$CV_w \cong \alpha^{-0.92} \quad (A1.3)$$

NOTE A1.2—The above approximation is within 1 % of the exact solution for CV_w values between 0.09 and 0.50. An exact relationship of CV_w and α is shown in Appendix X3.

A1.5 *Data Confidence Factor, Ω*—The data confidence factor accounts for uncertainty associated with data sets (**2**). This factor, which is a function of coefficient of variation, sample size, and specified percentile, is applied as a multiplier on the distribution estimate. Table A1.1 provides data confidence factors appropriate for lower fifth-percentile estimates.

NOTE A1.3—When a distribution tolerance limit is developed on a basis consistent with Ω, the data confidence factor is taken as unity.

A1.6 *Reliability Normalization Factor, K_R*—The reliability normalization factor, K_R, which is a function of CV_w and is generated for specific target reliability indices, is used to adjust the distribution estimate (for example, $R_{0.05}$) to achieve a target reliability index. The reliability normalization factor is the ratio of the computed resistance factor, ϕ_c (X1.8.5), to the specified resistance factor, ϕ_s (Table 1), adjusted by a scaling factor, which is a function of CV_w and is generated for specific target reliability indices. The K_R values presented in Table A1.2 were computed at a live-to-dead load ratio of 3. Computations (FORTRAN code listings reflecting 1980's methodologies) for determining reliability indices are contained in **Refs** (**3**) and (**4**). Calculations to derive input parameters for reliability analyses are outlined in **Ref** (**5**).

TABLE A1.1 Data Confidence Factor, Ω on $R_{0.05}$, for Two-Parameter Weibull Distribution with 75 % Confidence[A]

CV_w	Sample Size, *n*									
	30	40	50	60	100	200	500	1000	2000	5000
0.10	0.95	0.95	0.96	0.96	0.97	0.98	0.99	0.99	0.99	1.0
0.15	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	0.99	0.99
0.20	0.89	0.91	0.92	0.93	0.94	0.96	0.98	0.98	0.99	0.99
0.25	0.87	0.88	0.90	0.91	0.93	0.95	0.97	0.98	0.98	0.99
0.30	0.84	0.86	0.88	0.89	0.92	0.94	0.96	0.97	0.98	0.99
0.35	0.81	0.84	0.86	0.87	0.90	0.93	0.96	0.97	0.98	0.99
0.40	0.79	0.81	0.84	0.85	0.89	0.92	0.95	0.96	0.97	0.98
0.45	0.76	0.79	0.82	0.85	0.87	0.91	0.94	0.96	0.97	0.98
0.50	0.73	0.77	0.80	0.81	0.86	0.90	0.94	0.95	0.97	0.98

[A] Interpolation is permitted. For CV_w values below 0.10, the values for 0.10 shall be used.

A1.7 *Presentation of Results*:

A1.7.1 Report the sampling plan and testing in accordance with applicable standards. When lower tail data sets are used, report the sample size and data used in the calculations. Report the estimated shape and scale parameters along with the calculated coefficient of variation. When appropriate, also report the mean and standard deviation (derived from the calculated coefficient of variation). Include a plot showing the data points and fitted Weibull distribution. In addition to these basic parameters, also report the data confidence factor, Ω, calculated percentile estimate, R_p, reliability normalization factor, K_R, and reference resistance, R_n.

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

TABLE A1.2 Fifth-Percentile-Based Reliability Normalization Factors, K_R

CV_w,%	K_R					
	Compression and Bearing	Bending	Tension Parallel	Shear (2.1 basis)	Shear (SCL, 3.15 basis)	Shear (I-Joist, 2.37 basis)
10	1.30	1.25	1.35	1.40	0.95	1.25
15	1.30	1.25	1.30	1.40	0.95	1.25
20	1.20	1.15	1.25	1.30	0.90	1.15
25	1.15	1.10	1.15	1.25	0.80	1.10
30	1.05	1.00	1.05	1.15	0.75	1.00

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY TO THE TEXT

X1.1 *Commentary to the Introduction*:

X1.1.1 Load and resistance factor design (LRFD) is a design format. LRFD is a subset of a broader design methodology known as reliability-based design (RBD). The distinction between the two design procedures is significant. RBD implies, and often calculates, quantities related to the reliability of a member under a given set of conditions. A higher reliability corresponds to a lower probability of failure. One practical concern that arises when one attempts to apply RBD to real structural applications is that the calculations must idealize both the loads and the structural system response to reduce it to a mathematically tractable problem. This idealization process reduces the final calculation to a theoretically interesting, but often inapplicable, number. LRFD was developed by selecting a few of the basic concepts of RBD and using them to develop a format that is similar in many ways to current (allowable stress) design. LRFD provides incremental improvements in the design process in this way. The improvements provided by LRFD include the following:

X1.1.1.1 Consideration of the variability of various types of loads when assessing safety factors.

X1.1.1.2 Consideration of the consequences of various potential failure modes in a structure.

X1.1.1.3 Material resistance values that relate more closely to test data (member capacities).

X1.1.1.4 Consideration of resistance variability.

X1.1.2 Previous standards for developing allowable properties for many types of wood-based products directed the user to various ways of computing a population lower fifth-percentile estimate. This single number was the basis for an allowable strength property assignment. At the other extreme, a realistic RBD would require an accurate definition of a large portion of the lower tail of the material distribution and a large portion of the upper tail of the load distribution. LRFD requires somewhat more information than current procedures (for example, reference values and variability) but substantially less than RBD. In the most advanced LRFD procedures in use today, one needs only a distribution type and the parameters that describe that distribution. Refinements of these procedures suggest that estimates of the distribution and its parameters give the most accurate reliability estimates when they represent a tail portion of the distribution rather than the full distribution. This reflects the fact that, for common building applications, only the lower tail of the resistance and upper tail of the load distribution contribute to failure probabilities.

X1.1.3 Simulations have shown that the assumed distribution type can have a strong effect on computed LRFD resistance factors. However, much of this difference is due to the inability of standard distribution forms to fit the tail data precisely. By standardizing the distribution type, this procedure provides a consistent means for deriving these factors. In addition, by permitting tail fitting of the data, it provides a way of fitting data in this important region that is superior to full-distribution types.

X1.1.4 While the two-parameter Weibull distribution is the underlying basis for these calculations, the user of this specification is not burdened with applying statistical decisions. For LRFD purposes, the user must calculate the shape and scale parameters for the fitted Weibull distribution using the equations in the specification. All remaining steps in the calculations of a reference resistance are spelled out in the equations of the specification.

X1.2 *Commentary to Section 1, Scope*—The calculation procedures identified in this specification are common statistical procedures. This specification gives the user a document for all calculations necessary to develop LRFD reference resistances. Format conversion per Section 4.2 and test-based derivation per Annex A1 represent two separate approaches for determination of reference resistance for LRFD. Due to the sensitivity of reliability to changes in some of the parameters, these procedures offer a limited set of options to ensure that LRFD reference resistances are generated in a consistent manner. Other methods for computing reference resistance that are beyond the scope of this standard are discussed in Appendix X4.

X1.3 *Commentary to Section 3, Terminology*:

X1.3.1 The term "coefficient of variation" is specifically defined in terms related to the shape parameter of a 2-parameter Weibull distribution as used in Annex A1.

X1.3.2 The term "factored resistance" is specifically defined to differentiate it from the nominal (reference) resistance.

X1.3.3 The term "nominal resistance" is the most widely used term in reliability analysis and material specifications. As described in **Ref (6)**, users are cautioned that the term "nominal" has been defined in various ways over the years. This standard focuses on the term "reference resistance," used in the NDS.

X1.3.4 The term "reference conditions" is added to clarify that the design checking equations presented in this specification do not include notations for the myriad of potential end-use adjustment factors that might be applicable to specific designs. The rationale is that all end-use adjustment factors, with the notable exceptions of the load duration factor in ASD and the time effect factors in LRFD, are identical in both design formats and will mathematically cancel in the calculation of the ratio R_n / F_x. Users are cautioned to include all applicable adjustment factors in actual designs.

X1.3.5 The term "reference resistance" is retained as the primary terminology in this version of the standard for continued compatibility with the NDS **(7)** and other design documents, but its definition is clarified to indicate that it does not include the resistance factor (ϕ), the time-effect factor (λ) and other adjustments for end-use conditions that will be subsequently applied in the design checking equation.

X1.3.6 As discussed in **Ref (8)**, an underlying assumption in virtually all reliability analyses is that every adjustment factor applied in the design checking equation applies equally across the entire resistance population. From an analysis standpoint, this results in identical reliability indices for the reference and adjusted design cases.

X1.3.7 **Ref (8)** also describes the difficulty of applying the same judgment to the time effect factor (λ). The time effect factor is different from other design adjustment factors in two respects. First, it represents an interaction between the load side and the resistance side of the design equation. This fact leads to a dilemma regarding the format of the design checking equation: should the time effect factor be expressed separately (that is, $\lambda\phi_s R_n$) or embedded into the adjusted resistance like other adjustment factors? Second, test specimens at the lower tail of the strength distribution exhibit shorter times to failure under constant load than those higher in the distribution, while most of those at the upper end don't fail at all, because they are effectively loaded at a lower stress ratio.

X1.4 *Commentary to Section 4.2, Format Conversion*—Format conversion is the method used to develop format conversion factors to adjust reference ASD design values (based on normal 10-year load duration) to LRFD reference resistances (based on 10-minute load duration). Format conversion factors in Table 2 are developed to provide similar member and connection sizes when considering specific ASD and LRFD load cases and specified values of the resistance factor, ϕ, for LRFD as provided in Table 1.

X1.5 *Commentary to Table 2, Format Conversion Factor, K_F, for Compression Parallel to Grain, Bending, Tension Parallel to Grain, Shear, Radial Tension and Connections*:

X1.5.1 The format conversion factors for compression parallel to grain, bending, tension parallel to grain, shear, radial tension and connections that are subject to load duration or time effect adjustments, can be obtained from Eq X1.2.

X1.5.2 The factor of 2.16 is the algebraic solution at the calibration point, the ratio of R_n / F_x for S/D = 3, λ = 0.80, and C_D = 1.15.

$$LRFD\text{: } \lambda\phi R_n \geq 1.2D + 1.6(L \text{ or } S) \quad \text{(X1.1)}$$

$$ASD\text{: } C_D F_x \geq D + (L \text{ or } S) \quad \text{(X1.2)}$$

where:

λ	=	time effect factor (LRFD),
ϕ	=	specified resistance factor (LRFD),
R_n	=	reference resistance value (LRFD),
D, L, S	=	dead, live, and snow load effects, respectively,
C_D	=	load duration factor (ASD), and
F_x	=	ASD design value (ASD).

Substituting and solving for K_F (= R_n / F_x):

$$K_F = 2.16/\phi_s \quad \text{(X1.3)}$$

X1.5.3 Use of a single constant for the format conversion factor, K_F, is appropriate, based on the judgment of the committee, over a broad range of design cases. As shown in Fig. X1.1, this judgment produces exact calibration between ASD and LRFD for one specific design case (S/D = 3, C_d = 1.15, λ = 0.8). Differences between ASD and LRFD designs will result for other design cases. The algebraic format conversion solution for the precise constant in the numerator of Eq X1.3 is not to be confused as the RBD basis supporting Eq X1.3 (see Commentary to Annex A1). The RBD basis of the format conversion factor involved first order, second moment reliability methods to graph R_n/F_x across a range of load ratios for three distinct live-load cases (occupancy floor, snow roof, and non-snow roof), where R_n and F_x come directly from the LRFD and ASD design equations. The factor in the numerator of Eq X1.3 is in the range from 2.1 to 2.2 and resulted from the application of engineering judgment as a balance of increases for floors at low L/D ratios versus decreases for non-snow roofs at higher L/D ratios.

X1.6 *Commentary to Table 2, Format Conversion Factor, K_F, for Lateral Buckling (Stability), Compression Perpendicular to Grain, and Rolling Shear not subject to load duration or time effect adjustments*:

X1.6.1 The format conversion factors for lateral buckling (stability), compression perpendicular to grain, and rolling shear values that are not subject to load duration or time effect adjustments, can be obtained from Eq X1.4:

$$K_F = 1.5/\phi_s \quad \text{(X1.4)}$$

X1.6.2 The precise factor of 1.5 in the numerator is based on a calibration at the reference condition assuming a live load (L) to dead load (D) ratio of L/D = 3 and the assumption that modulus of elasticity for beam and column stability (E_{min}), compression perpendicular to grain, and rolling shear are not subject to load duration or time effect adjustments. The calibration was done as follows: