Designation: D 6815 – 02a

Standard Specification for Evaluation of Duration of Load and Creep Effects of Wood and Wood-Based Products[1]

This standard is issued under the fixed designation D 6815; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides a procedure for testing and evaluating duration of load and creep effects of wood and wood-based materials relative to an accepted duration of load adjustment model. This specification was created for products that are currently covered by a consensus standard (for example, lumber, structural composite lumber and structural-use panels). This procedure is intended to demonstrate the engineering equivalence to the duration of load and creep effects of visually graded lumber as specified in Practice D 245 for a product under evaluation used in dry service conditions. This procedure is not intended to evaluate the performance of products under impact loading. Quantification of specific duration of load or creep factors is beyond the scope of this specification. For further guidance regarding the applicability of this specification refer to X1.1 in the Commentary.

1.2 Use of the procedure in this specification to determine equivalence to the Practice D 245 duration of load relationship is limited to solid wood and wood-based products whose long term load behavior is similar to that of solid wood. Equivalence demonstrated in this specification is dependent upon evaluation of a product's 90-day (minimum) creep-rupture performance. In this evaluation, three criteria must be satisfied: (*1*) adequate strength over a 90-day period, (*2*) decreasing creep rate, and (*3*) limited fractional deflection. A summary of the development of these criteria and the underlying assumptions behind them is provided in the Commentary in Appendix X1 and Appendix X2.

1.3 Long term degradation phenomena not described by a creep-rupture model are not addressed in this standard (see Commentary X1.2.4).

2. Referenced Documents

2.1 *ASTM Standards:*

D 9 Terminology Relating to Wood[2]

D 198 Test Methods of Static Tests of Lumber in Structural Sizes[2]

D 245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber[2]

D 1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particleboard Panel Materials[2]

D 2915 Practice for Evaluating Allowable Properties for Grades of Structural Lumber[2]

D 3043 Test Methods for Structural Panels in Flexure[2]

D 4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials[2]

D 4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material[2]

D 5457 Specification for Computing the Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design[2]

E 4 Practices for Force Verification of Testing Machines[2]

E 6 Terminology Relating to Methods of Mechanical Testing[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[2]

3. Terminology

3.1 *Definitions*—See Terminologies D 9 and E 6, and Practices E 4 and E 177 for definitions of terms used in this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *breadth*—the dimension of the test specimen in the direction perpendicular to the span and perpendicular to the direction of an applied bending load.

3.2.2 *creep*—the time-dependent increase of deformation of the test material under a constant load.

3.2.3 *creep deflection*—total measured deflection at a specific time minus the initial deflection.

3.2.4 *creep rate*—the change in creep deflection over time.

3.2.5 *creep-rupture*—a failure phenomenon described by a relationship between applied stress and time-to-failure.

3.2.6 *depth*—the dimension of the test specimen in the direction perpendicular to the span and parallel to the direction of an applied bending load.

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[2] *Annual Book of ASTM Standards*, Vol

3.2.7 *dry service conditions*—the conditions in most covered structures, where the moisture content of lumber will not exceed 19 % **(1)**.[3]

3.2.8 *duration of load factor*—a factor customarily used to account for the effect of duration of load on the strength of wood products.

3.2.9 *failure*—the point at which the test member can no longer support the applied constant load.

3.2.10 *fractional deflection*—a ratio of total deflection to the initial deflection.

3.2.11 *initial deflection*—the deflection at approximately one minute after the application of load.

3.2.12 *span*—the distance between the centerlines of end reactions on which a test specimen is supported to accommodate a transverse bending load.

4. Significance and Use

4.1 This specification provides a method for evaluating duration of load and creep effects of wood and wood-based products subjected to bending stress. This method is intended to demonstrate the engineering equivalence to the duration of load and creep effects of visually graded lumber as specified in Practice D 245 for a product under evaluation. Equivalence is based on evaluating a product's creep-rupture performance over a minimum of 90 days and meeting the requirements of this specification. This specification does not attempt to quantify the effect of damage accumulation or to establish product-specific duration of load factors for the product under evaluation.

5. Test Methods and Acceptance Criteria

5.1 *Test Methods*:

5.1.1 A test population shall be sampled from production that is representative of the product under evaluation. Two matched test groups shall be selected, one for short-term bending tests, and one for long-term creep-rupture bending tests. A minimum sample size of 28 is required for each test group. If further testing is contemplated, additional test specimens shall be sampled from the initial test population. Long-term and short-term test specimens shall have the same cross section dimensions and length.

NOTE 1—Matching is a technique that attempts to subdivide the initial sample population into two or more separate groups that possess near identical distributional form and scale for bending properties. Matching specimens for the purposes of 5.1.1 should be done with care, considering errors introduced by the process and the characteristics of the material under test.

5.1.2 Each test specimen shall be simply supported and loaded by two equal concentrated forces spaced a distance of one-third the total span from the end supports (that is, third-point bending). Loads shall be applied in the product orientation that represents the general intended use of the product.

5.1.2.1 For joist-form materials, the span to depth ratio shall be as specified in applicable test standards (see Note 2). Lateral restraints shall be used when necessary to maintain lateral stability. The minimum test specimen cross section shall be 2.5 in. (63.5 mm) in depth and 1.0 in. (25.4 mm) in width.

NOTE 2—For lumber sized products, span to depth ratios typically used for flexural tests range between 17 and 21.

5.1.2.2 For sheathing-form materials, the test span shall be not less than 48 times specimen thickness or 24 in., whichever is greater. The specimen width for all sheathing-form materials shall not be less than 12 in. (305 mm).

5.1.3 Moisture content shall be measured on the short-term specimens immediately after destructive testing and on the long–term specimens at the termination of the long–term test. Measurement of moisture content shall be in accordance with Test Methods D 4442. The average moisture content of all the long-term test specimens shall not deviate more than ±2 % from the average moisture content of all the short–term test specimens (see Note 3).

5.1.4 The test environment temperature and relative humidity shall be recorded daily (see Commentary X1.4.5).The daily average temperature of the test environment shall not decrease more than 5°C (9°F) below the temperature at which the short–term tests were conducted. At no time shall the test environment reach a temperature less than 0°C (32°F).

NOTE 3—Conditioning the short-term and long-term test material for at least 30 days in the anticipated test environment conditions generally provides compliance with the ±2 % moisture content change criterion.

NOTE 4—In experiments where the temperature falls below the prescribed limit, it may be possible to demonstrate the validity of the data by continuing the experiment for an additional time period at least equal to, and possibly greater than, the amount of time the temperature was below the prescribed limit.

5.2 *Short-Term Bending Tests*:

5.2.1 The loading rate for the short-term tests shall be such that the sample target failure load would be achieved in approximately 1 min. Failure load shall not be reached in less than 10 s nor more than 10 min. The procedures of Test Methods D 198 or D 4761 shall be followed for joist-form materials and Test Methods D 1037 or D 3043 for sheathing-form materials.

5.2.2 The sample standard deviation and the lower five percent point estimate of the short-term test group (5 % PE) shall be determined in accordance with Practice D 2915.

5.3 *Creep-Rupture Bending Tests*:

5.3.1 The creep-rupture test specimens shall be loaded such that the average time to attain the pre-selected constant stress level does not exceed the average time to failure of the short-term tests (see 5.2.1). Thereafter, the specimens shall be subjected to the constant stress for a minimum period of 90 days. During this period, mid-span deflection readings shall be taken for each test specimen, until the 90-day time period has elapsed or until the occurrence of a failure. At a minimum, the deflection readings shall be taken at approximately one minute after the application of the constant load (initial deflection), and at the end of one hour, day 1, day 7, day 14, day 30, day 60, and day 90. When better characterization of the creep rate is desired, more frequent deflection measurements should be taken. Additional deflection readings are required when the test

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

extends beyond 90 days. When a specimen failure occurs, time-to-failure shall be recorded.

5.3.2 The specimens selected for these tests shall be tested at a constant stress level, f_b, as determined in accordance with Eq 1 (see Commentary Appendix X1).

$$f_b = 0.55 \times (5\ \%\ PE) \tag{1}$$

where:

f_b = minimum applied bending stress, and
5 % *PE* = the lower five percent point estimate, as determined from the short-term bending tests in 5.2.

The creep rate, fractional deflection (FD), and the total number of failures at 90 days (N_{90}) (or greater) shall be used to evaluate the acceptance of the product.

NOTE 5—Examples of acceptable creep and creep-rupture test apparatus are given in Refs **2,3**.

5.4 *Acceptance Criteria*—The product is considered acceptable for using the duration of load and creep factors applicable to lumber if the following three criteria are all satisfied: (*1*) adequate strength over the test duration, (*2*) decreasing creep rate, and (*3*) a limited fractional deflection.

5.4.1 *Adequate Strength*—The total number of failures over the test duration shall be used to determine acceptance.

5.4.1.1 The total number of failures at 90 or more days shall be less than the critical order statistic, N_c, of the lower 5 % non-parametric tolerance limit with 75 % confidence:

$$N_{90} < N_c \tag{2}$$

where:

N_{90} = number of specimen failures at the end of the 90-day test period, and
N_c = critical order statistic used to estimate the lower 5 % non-parametric tolerance limit based on the number of specimens under long-term load (see Note 6).

For example, if 53 specimens are used in the creep-rupture tests, then $N_c = 2$ and no more than one specimen shall fail within the 90-day period ($N_{90} \leq 1$) for the product to be accepted as meeting the adequate strength criterion. Alternatively, if 28 specimens are tested, then $N_c = 1$, and no failures shall occur ($N_{90} = 0$).

5.4.1.2 If the requirement of 5.4.1.1 is not met and the number of failures at 90 days is greater than or equal to the critical order statistic ($N_{90} \geq N_c$) then the product under evaluation fails to meet the adequate strength criterion with the sample population, *N*.

5.4.1.3 If the number of failures at 90 days is equal to the critical order statistic ($N_{90} = N_c$) in 5.4.1.2, then additional testing may be conducted. In this case the sample population shall be increased by sampling an additional set of matched specimens per 5.1.1 sufficient to allow the use of a higher non-parametric order statistic (see Note 6). The additional specimens shall be tested for another 90-day test duration. The adequate strength requirement of 5.4.1.1 is met when, at the end of the additional testing, the combined number of specimen failures during these two test series (N_{90} combined) is less than the critical order statistic (N_c combined) based on the combined number of specimens evaluated (*N* combined).

NOTE 6—From Practice D 2915 the order statistic for the lower 5 % tolerance limit with 75 % confidence, N_c, for various sample populations, *N*, is as follows:

N	28	53	78	102
N_c	1	2	3	4

5.4.2 *Decreasing Creep Rate*—All the test specimens that do not fail during the 90 day constant load time period shall show a decreasing creep rate.

5.4.2.1 To determine a decreasing creep rate, the change in creep deflection shall be calculated between a minimum of three equally spaced time segments. The change in calculated creep deflection shall progressively decrease for each specimen. For the three equal time periods of 0 to 30 days, 30 to 60 days and 60 to 90 days, the decreasing creep rate can be expressed as (see Commentary Appendix X2):

$$D_{30} - D_i > D_{60} - D_{30} > D_{90} - D_{60} \tag{3}$$

where:

D_i = initial deflection (measured one-minute after application of the load per 5.3.1), and
D_{30}, D_{60}, D_{90} = deflections measured on 30th, 60th and 90th day respectively.

NOTE 7—To better define the creep rate, additional segments with a shorter frequency (for example, five 18-day segments) may be used.

5.4.2.2 If the creep rate for a given specimen is not decreasing at the end of the 90-day period, the time period shall be extended for a minimum of 30 additional days. The change in calculated creep rate for the additional time segment(s) after 90 days shall progressively decrease relative to the preceding segment.

NOTE 8—The creep rate may fluctuate due to environmental changes in relative humidity or temperature, or both. Extending the test beyond the 90-day period in a controlled environment may demonstrate that the beams were not exhibiting tertiary behavior at the end of the time period.

5.4.3 *Fractional Deflection*—Fractional deflection after ninety (90) days for each surviving specimen shall not be greater than 2.0:

$$FD_{90} = \frac{D_{90}}{D_i} \leq 2.0 \tag{4}$$

where:

D_i = initial deflection (measured one-minute after application of the load per 5.3.1), and
D_{90} = deflection measured on 90th day.

6. Report

6.1 The report content depends on the type of tests conducted. As a minimum, the report shall include the following information:

6.1.1 Description of the material under evaluation, including species, grade (or grade combination), specimen geometry, and grain orientation, and other specific process parameters involved in its manufacture.

6.1.2 Description of the sampling and matching protocol used.

6.1.3 Descriptions of the test setup, including detailed drawings, the span, and the deflection measuring apparatus.

6.1.4 Description and frequency of calibration procedures.

6.1.5 Records of test environmental conditions.

6.1.6 Test data, including (*1*) specimen moisture content, (*2*) applied loads, (*3*) deflection measurements at various test durations, (*4*) test specimen time-to-failure, (*5*) creep rate, and (*6*) fractional deflection for each surviving test specimen.

6.1.7 Statistical calculations, including parametric statistics on short-term bending tests (if applicable) and description of procedure used to calculate the five percent point estimate.

7. Precision and Bias

7.1 The precision of the provisions in this specification have not yet been determined. When data become available, a precision and bias statement will be included.

8. Keywords

8.1 creep rate; creep-rupture; duration of load; fractional deflection; lumber; structural composite lumber; structural-use panels

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY ON DURATION OF LOAD EFFECTS IN WOOD PRODUCTS

X1.1 Scope

X1.1.1 This appendix provides general background information on the underlying assumptions used in establishing the creep rupture (duration of load) evaluation procedures in this specification. The procedure in this specification was originally developed to provide for the evaluation of duration of load (DOL) and creep adjustment factors for structural composite lumber (SCL) products. Much research has since been conducted on SCL products to demonstrate their long-term load performance. It was considered important to provide the engineering community with a standard procedure for evaluating DOL effects in these and other wood products. It is the intent of the Committee to limit the application of the concepts in this specification to products that exhibit DOL effects similar to solid wood. Creep rupture tests of sawn lumber, structural composite lumber, plywood, and oriented strand board (X1.5.1-X1.5.3) indicate that wood products whose strength is controlled by the properties of the wood fibers, wood strand or other wood elements in the product exhibit degradation mechanisms generally similar to those of solid wood used to establish the DOL relationship in Practice D 245.

X1.1.2 This specification does not address the conditions of extremely rapid loading or impact loading. Consequently the sections in Practice D 245 related to this type of loading cannot be applied to new products evaluated with this specification. Verification of the DOL adjustment for impact load conditions requires separate evaluation and is considered beyond the scope of this specification.

X1.2 Background

X1.2.1 The phenomenon of creep-rupture, usually called the duration of load (DOL) effect in wood and wood-based products has been of particular interest to the wood science and timber engineering community as well as wood product manufacturers concerned with the introduction of new building products and implementation of new codes for engineering design in wood. Since the early 1970s, a significant amount of work has been conducted on measuring and empirically modeling the time-dependent strength behavior of structural size lumber. A historical perspective of this issue and a review of the major test studies conducted are provided by Barrett **(4)**.

X1.2.2 If new engineered wood products are to use the duration of load adjustments recommended in the design codes for solid sawn lumber and other wood-based products, an appropriate procedure for confirming the applicability of such use is needed.

X1.2.3 Through the use of a 90-day creep rupture experiment the procedures of this specification allow a comparison of the 90–day term load performance of a wood or wood-based product to that observed in solid sawn structural lumber as derived from the results of extensive tests on lumber of structural sizes.

X1.2.4 Typically, creep-rupture models are empirical, relying on events observable only at a macro level. This type of model, in the context of the proposed short term test, is only sensitive to the actual micro level degradation phenomena (chemical bonds) leading to failure when that degradation leads to creep or rupture during the test. The traditional DOL behavior as presented in Practice D 245 is based on observation and judgement of solid wood only. In that model, relatively short-term test results (like 90 days) appear to fit within a projection that can cover a longer period of degradation. However all degradation phenomena embodied in that statement of DOL are those of solid wood with limited processing. Materials or combinations of materials that may degrade under load and time with mechanisms different than those of solid wood may experience a different failure history than that predicted by the Practice D 245 model. This specification is not designed to project duration of load performance beyond the period of the test for processing methods or materials having degradation mechanisms different from traditionally dried solid wood (possible examples of this may be chemically modified wood products or wood-plastic composites). Some composite materials, such as plywood and glued laminated beams fabricated by traditional methods, may have test data and/or field experience that demonstrates degradation phenomena under load not significantly different from (or superior to) solid wood. Longer time intervals at the appropriate load levels are suggested where the failure mechanisms leading to measurable failure are not well understood or where field experience is limited.

X1.3 Duration of Load Results for Solid Sawn Structural Size Lumber

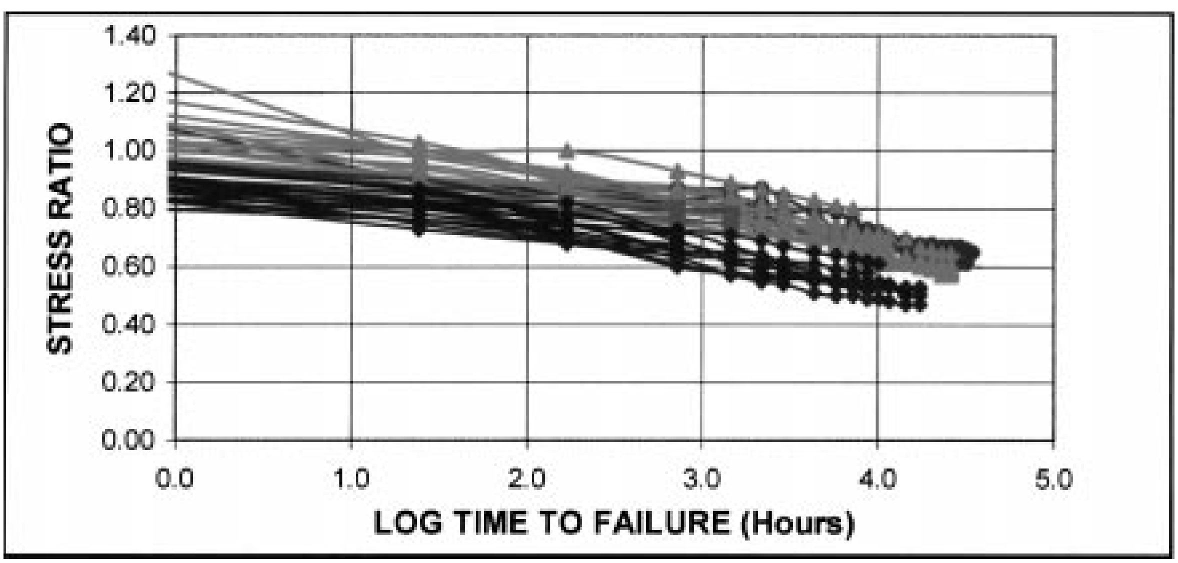
X1.3.1 Beginning in 1983, coordinated duration of load programs were initiated in the U.S. and Canada to investigate the effects of grade, species, loading mode, temperature, relative humidity and repeated loading on the duration of load response of lumber. The majority of this work has been previously summarized by Karacabeyli and Soltis **(5)**, and Karacabeyli and Barrett **(6)** based on the studies conducted at the Forest Products Laboratory, Madison, WI and at Forintek Canada, Vancouver, BC. The summary in this Appendix includes only those studies conducted under constant load in bending.

X1.3.2 In total over 4600 individual lumber specimens from over 40 separate test groups representing four wood species (Douglas-fir, western hemlock, white spruce, and southern pine) in various grades and sizes were placed under constant long-term load in bending. The range of grades included Select Structural, No. 2 and better and a test series with three quality levels labeled as High, Medium and Low. Beam sizes included nominal 2 by 4, 2 by 6 and 2 by 8-in. lumber. Time under constant load ranged from one week to four years among the various studies. All studies were conducted in constant 20°C (68°F), 50 % relative humidity or ambient in-door conditions.

X1.3.3 Time-to-failure data collected from each of these studies was analyzed using the Stress Ratio approach. This approach involved testing matched sets of members. The first set was tested according to standard short-term flexure tests methods, usually producing failure in one to five minutes. The second set was then loaded to produce a constant stress in all members, usually to some fractile in the distribution of the short-term strength, and times-to-failure were recorded. Stress ratios were then determined using the Equal Rank Assumption, which assumes that the order of failure for the constant load members is the same as that for the standard short-term tests. The stress ratio was then calculated as the ratio of the applied constant load stress to the ranked stress from the standard short-term tests (Note X1.1).

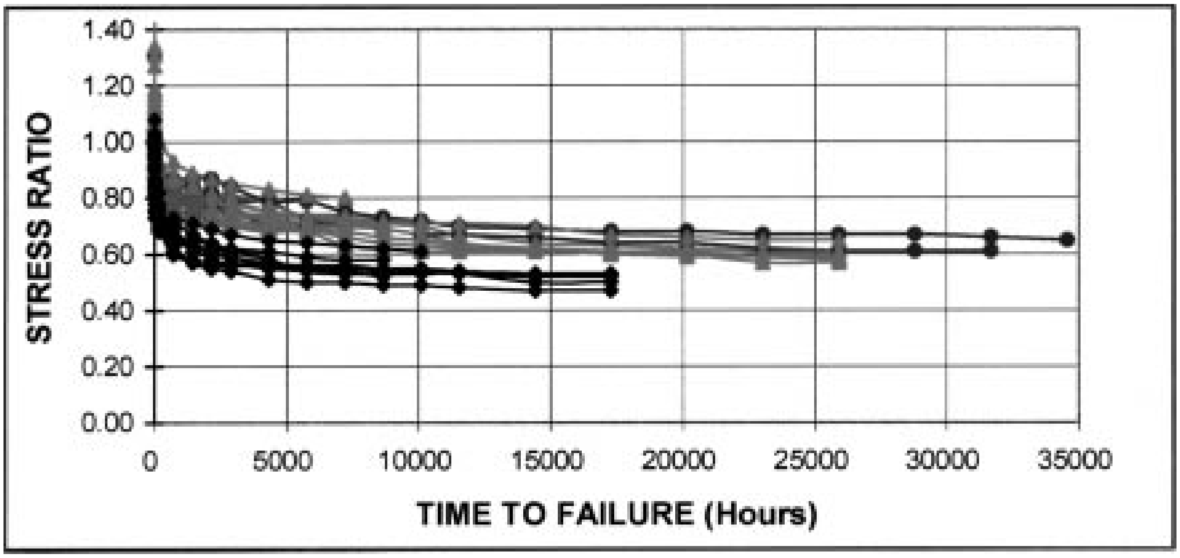
NOTE X1.1—The following example is intended to illustrate the use of the equal rank assumption as a basis for determining stress ratios and does not relate to the actual lumber test data or duration of load estimates provided in this Commentary. Start with a short-term test consisting of 100 specimens. Assume that the strength of the weakest five specimens was 1000 psi, 1100 psi, 1200 psi, 1300 psi, and 1400 psi, respectively. Assume that the stress level chosen for the long-term testing of 50 specimens is 1000 psi. In the long-term test group, the first piece to fail (call it piece A) is at the 2nd percentile (1 out of 50) of its group; the second piece (call it piece B) is at the 4th percentile, and so on. The equal rank assumption estimates that the (unknown) short-term strength of piece A is the same as the 2nd percentile piece in the control group or 1100 psi. Similarly, the short-term strength of piece B is estimated as 1300 psi (same as the 4th percentile of control group). This procedure assumes that we've actually loaded piece A to 91 % of its short term strength (1000/1100) and that we've loaded piece B to 77 % (1000/1300) of its short-term strength. So, when piece A fails, its time to failure (*x*-axis) will be paired with a stress ratio of 0.91. Similarly, when piece B fails, its time to failure will be plotted with a stress ratio of 0.77.

X1.3.4 Stress ratio versus time-to-failure plots for these studies are shown in Figs. X1.1 and X1.2 for logarithmic and real time scales respectively. The broad band of data observed is considered to be representative of the duration of load behavior of structural solid sawn wood based on the Stress Ratio approach.



NOTE—Results are for Western Hemlock—No. 2 & Btr 2 by 6 (38 by 140 mm); White Spruce—Quality 1 2 by 8(38 by 184 mm), Quality 2 2 by 8 (38 by 184 mm), Quality 3 2 by 4 (38 by 89 mm); Douglas-fir—Sel. Str., No.2 & Btr 2 by 4 (38 by 89 mm), 2 by 6(38 by 140 mm); Southern pine—No.2 & Btr 2 by 4 (38 by 89 mm) High Temperature Dried, CCA treated.

FIG. X1.1 Stress Ratios for Structural Lumber (Log Time)



NOTE—Species, grades and sizes are the same as Fig. X1.1.

FIG. X1.2 Stress Ratios for Structural Lumber (Real Time)

X1.3.5 Comparison of the average, minimum and maximum stress ratios for the lumber data to the Madison Curve is shown in Fig. X1.3. The lumber average trend line is similar to the Madison Curve for the time period of 1 h to approximately 1 year after which the two lines begin to diverge.

X1.4 Duration of Load Evaluation Procedure

X1.4.1 The evaluation procedure in this specification uses the structural lumber stress ratio results to define the minimum performance requirements expected for wood and wood-based products. Fig. X1.4 shows the observed stress ratio results for structural lumber when Fig. X1.2 is redrawn to reflect a six-month constant load time period. The minimum, average, and maximum stress ratios observed are shown in Table X1.1. This range characterizes the duration of load behavior of structural solid sawn lumber. All wood and wood-based products should meet these minimum stress ratio values if their duration of load behavior is to be considered "like structural lumber".

X1.4.2 From Table X1.1, the minimum stress ratio for three months of constant load is 0.55. This result is interpreted to mean that a wood member stressed to 55 % of its ultimate short term strength for a three month time period should not fail if its duration of load performance is characteristic of structural lumber. Since the strength of any one particular piece of lumber is not known with absolute certainty it is necessary to measure the short term strength of a large number of pieces to characterize its bending strength distribution and determine its 5 % tolerance limit (TL). Based on a non-parametric estimate of the 5 % TL this approach is interpreted to mean that in a lumber test population loaded to 55 % of its 5 % TL strength, no more than 0 in 28 or 1 in 53 beams should fail after three

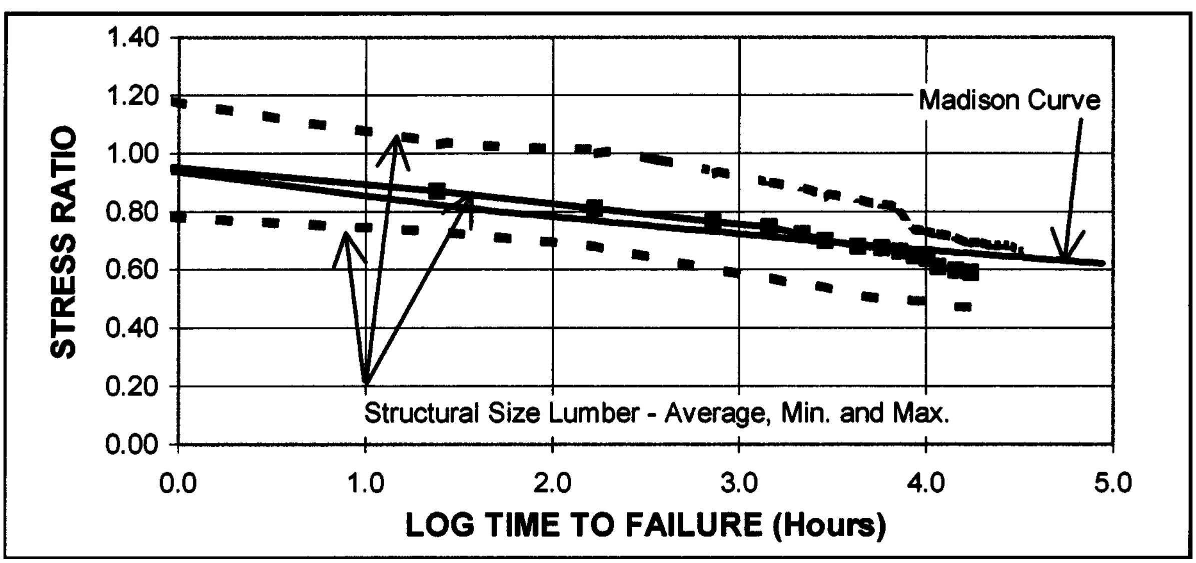


FIG. X1.3 Madison Curve Compared to Lumber Average, Minimum and Maximum Stress Ratios

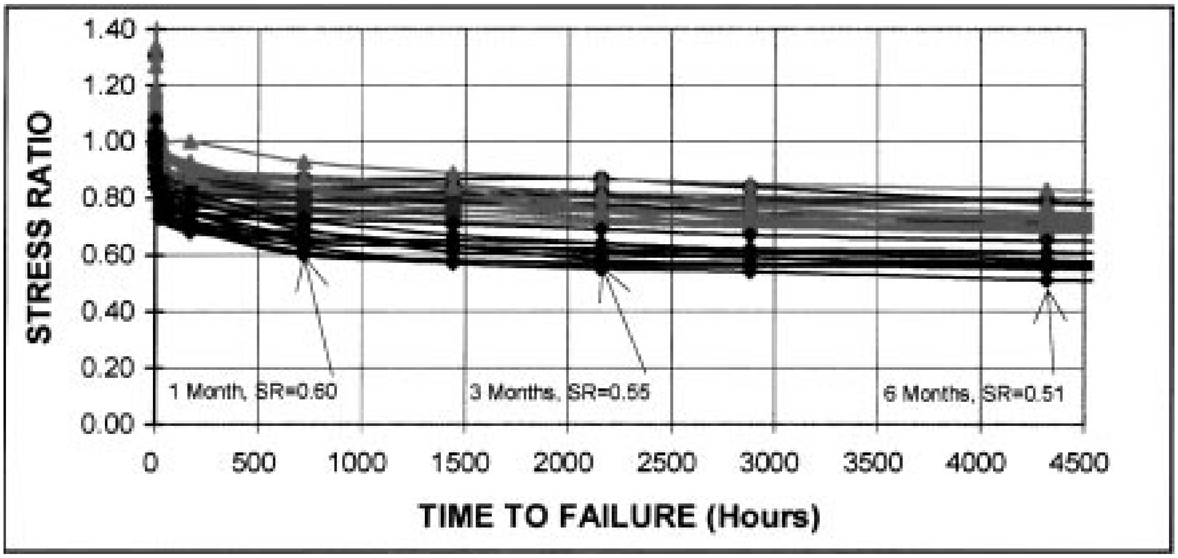


FIG. X1.4 Stress Ratios for Structural Lumber (0 to 6 Months Real Time)

TABLE X1.1 Structural Lumber Stress Ratios from Fig. X1.4

Time (months)	Stress Ratio		
	Min	Average	Max
1	0.60	0.76	0.93
3	0.55	0.72	0.87
6	0.51	0.68	0.83

months of constant load. Similarly, from Table X1.1, if a lumber test population loaded to 60 % of its 5 % TL strength, no more than 0 in 28 or 1 in 53 beams should fail after one month under constant load.

X1.4.3 In the development of this specification it was the judgment of the committee that a stress ratio value of 0.55 and the minimum time under load of 3 months (90 days) be used in this evaluation procedure. At the 90 day test duration, selection of the 0.55 stress ratio would suggest that currently approved solid sawn products would meet the acceptance criteria of this specification. The additional requirements that all test beams show a decreasing rate of creep and a maximum fractional deflection limit for the three month period were also specified to ensure that the beams were not entering into tertiary creep and eventual failure (see Commentary Appendix X2). The 5 % point estimate derived from the short-term bending tests provides an estimate of the 5 % tolerance limit of the 90-day bending tests using the Equal Rank Assumption, described in X1.3.3.

X1.4.4 The choice of a three month test duration for the long-term test was based on both mathematical and engineering considerations. The mathematical consideration was that a 3-month duration would be expected to measure approximately ¾ of any creep-rupture effects predicted by the Madison Curve and that test durations of 30 to 50 years would be required to quantify the remaining ¼. The engineering consideration was that the design loads are established based on near-maximum expected load events and that duration of several months is a reasonable maximum duration for an extreme load event.

X1.4.5 *Test Environment Conditions*—Dry service conditions are specified as the environmental conditions for conducting the long term load tests since these were the test conditions from which the results in Fig. X1.4 were developed (see X1.3.2).

NOTE X1.2—Because large (sometimes full-size) test specimens will be used for these tests it may be difficult to find conditioning chambers of sufficient size to accommodate all of the 28 or more test frames needed to conduct the tests simultaneously. Since dry service conditions do not specify a temperature or relative humidity condition, the producer may set up tests in a covered building where the temperature will not go below the freezing point of water. An additional lower temperature range restriction of 5°C (9°F) relative to the temperature at which the short-term tests were conducted has also been specified. This restriction is to minimize temperature effects on the material's strength and stiffness **(9)** to within a few percent of the material properties established at the short-term test temperature conditions. Given that creep and creep-rupture tests of wood-based products typically show accelerated deformations in cyclic environments, either a temperature controlled covered building or controlled constant environmental conditions are acceptable.

X1.4.6 This approach is considered to be a pass-fail procedure and does not attempt to develop a duration of load factor for a specific product. A wood or wood-based product that meets the criteria of this evaluation procedure is considered to exhibit duration of load performance which is not more severe than that represented by the accepted model for structural lumber and therefore the duration of load factors in Practice D 245 can be applied. Using this approach allows for the evaluation of the duration of load performance of new wood and wood-based products in a reasonable time period and without great expense.

X1.4.7 Although this procedure evaluates duration of load performance in bending, it is the committee's intent that the duration of load factors in Practice D 245 be applicable to other structural properties consistent with solid sawn lumber practice. Reference should be made to Practice D 245 for a description of the limitations of these adjustment factors.

X1.5 Example Evaluations

X1.5.1 Karacabeyli **(7)** evaluated the criteria of this specification for a group of No.2 grade Douglas-fir lumber. A total of 28 nominal 2 by 6-in. test beams were loaded to 60 % of the fifth percentile of the one-minute ramp loading test group's strength distribution and held under constant load for over three months. No failures were observed during the three-month time period and all test beams showed a decreasing creep rate.

X1.5.2 Sharp and Craig **(8)** reported that this evaluation criterion can be used to differentiate between structural composite lumber (SCL) products that exhibit duration of load performance consistent with structural lumber with those that do not. Information was provided for a number of SCL products to show conformance within the range of performance observed for structural lumber.

X1.5.3 Laufenberg et al. **(3)** conducted creep-rupture tests on commercially representative structural-use panels (plywood and OSB). Based on the results, no failure would occur over a 3-month period when subject to a constant bending stress level of 0.55.

X2. COMMENTARY ON CREEP EFFECTS IN WOOD PRODUCTS

X2.1 Scope

X2.1.1 This appendix provides general background information on the underlying assumptions used in establishing the creep evaluation procedures in this specification.

X2.2 Background

X2.2.1 Creep is defined as the time-dependent deformation exhibited by a material under constant load. Practice D 245 refers to this phenomenon as plastic flow and recommends that it be limited to prevent excessive deformation in-service. An increased deflection factor of two is recommended with a note that the "increase may be somewhat greater where the timber is subjected to varying temperature and moisture conditions than where the conditions are uniform."

X2.2.2 For lumber, the design community has historically increased initial deflections by a factor of 2.0 for unseasoned lumber as a serviceability criterion. While this guideline has historically given successful serviceability, it does not reflect actual lumber creep performance at these environmental conditions. For example, the Wood Handbook states that "an increase of about 28°C (50°F) in temperature can cause a two- to threefold increase in creep. Green wood may creep four to six times the initial deformation as it dries under load."

X2.2.3 Given the absence of an existing, test-based, creep criterion for solid sawn lumber in dry-use conditions, the approach used in establishing the creep evaluation procedures was to specify a decreasing creep rate and to determine a maximum creep limit based on work conducted on solid sawn lumber evaluated during the development of this specification.

X2.2.4 When evaluating a product outside of dry-use conditions, the applied stress level and fractional deflection requirements in this Standard, which are based on solid sawn lumber may require further consideration, depending on product serviceability requirements, applied treatments and conditions in-service.

X2.3 Creep Results for Solid Sawn, Structural Composite Lumber and Structural Panels

X2.3.1 This specification requires that each test specimen surviving the 90-day constant load period exhibits a decreasing creep rate and a fractional deflection less than or equal to 2.0.

X2.3.2 Justification for a decreasing creep rate can be found in Practice D 245. The committee felt this criterion should be applied to each test specimen to ensure that no individual beam shows evidence of tertiary creep behavior and eventual failure.

X2.3.3 For the three equal time periods of 0 to 30 days, 30 to 60 days, and 60 to 90 days, the decreasing creep rate criteria can be expressed as:

$$D_{30} - D_i > D_{60} - D_{30} > D_{90} - D_{60} \quad \text{(X2.1)}$$

where:

D_i = initial deflection (measured one-minute after application of the load per 5.3.1), and

D_{30}, D_{60}, D_{90} = deflections measured on 30th, 60th and 90th day respectively.

X2.3.4 An example creep rate calculation is provided in X2.4. Other time periods similar to those in Eq X2.1 can be used provided a minimum of three equal time periods are chosen and represent the entire time under load.

X2.3.5 In cases where the individual creep rate increases due to fluctuations in the test environment temperature and relative humidity conditions or in the case of small increases related to deflection measurement accuracy, the test period should be extended another month (30 days) with more frequent measurements taken to substantiate that the increase is not due to the beam exhibiting tertiary creep behavior.

X2.3.6 Fractional deflection results from a number of studies **(3,7)** conducted on solid sawn lumber, structural composite lumber, and structural-use panel products, conducted in constant 20°C (68°F), 50 % relative humidity or ambient in-door conditions, are summarized in Table X2.1. Based on test results for solid sawn lumber it was the judgement of the committee that a maximum fractional deflection requirement of 2.0 be used in this evaluation procedure.

X2.3.7 The fractional deflection (*FD*) criteria as specified in 5.4.3 can then be expressed in equation form as:

$$FD_{90} = \frac{D_{90}}{D_i} \leq 2.0 \quad \text{(X2.2)}$$

where:

D_i = initial deflection (measured one-minute after application of the load per 5.3.1), and

D_{90} = deflection measured on 90th day.

X2.3.8 This fractional deflection criterion is applied to each test specimen to ensure that no individual beam shows excessive deflection which could lead to tertiary creep and eventual failure. The fractional deflection values shown in Table X2.1 are higher than what would be expected in actual deflection controlled applications over a three month period due to the higher applied loads.

TABLE X2.1 Fractional Deflection—*FD*

Product	Stress Level % of 5 % PE	No. of Specimens	Time Under Load (Months)	Fractional Deflection (*FD*)	
				Average	Maximum
Lumber - #2 D. fir	60[A]	30	3	1.63	2.01
LVL–1	47[B]	28	4	1.24	1.27
LVL–2	54[B]	28	4	1.34	1.41
LVL–3	55[A]	28	3	1.25	1.38
PSL–1	59[A]	34	3	1.31	1.46
PSL–2	59[A]	24	3	1.29	1.39
PSL–3	60[A]	63	3	1.31	1.43
Structural panels	15 and 30[C]	108	6	1.52	1.70

[A] Based on the ratio of applied constant stress to control group strength.
[B] Based on the ratio of applied constant stress to residual strength.
[C] Based on the ratio of applied constant stress to each matched specimen. The fractional deflection at 15 and 30 % stress levels was not significantly different.

X2.4 Example Fractional Deflection and Creep Rate Determination

X2.4.1 An example set of deflection data for a single LVL test specimen placed under constant load for 90 days is shown in Table X2.2. A plot of the total deflection versus time is shown in Fig. X2.1.

X2.4.2 Based on the equations in X2.3, the creep rate and fractional deflection were calculated and also summarized in Table X2.2. A plot of the fractional deflection and creep rate versus time is shown in Fig. X2.2.

X2.4.3 This test specimen showed acceptable creep performance since after 90 days it exhibited a decreasing creep rate and the fractional deflection was less than 2.0.

X2.4.4 As shown in Table X2.2 the difference between the 60-day and 90-day creep rates can be small and at times be comparable to the deflection measurement error. If this occurs, then it is difficult to determine if an observed increase in the 90-day creep rate is due to increased product creep or measurement error in the deflection measurement device. If this is observed then it is recommended that the deflection measurements be taken for at least an additional month at frequent time intervals and plotted to demonstrate that the creep rate is not increasing.

X2.4.5 This approach is considered to be a pass-fail procedure and does not attempt to develop creep factor for a specific product. A wood or wood based product that that meets the criteria of this evaluation procedure is considered to exhibit duration of load performance that is characteristic of structural lumber in dry-use conditions.

TABLE X2.2 90-Day Creep of LVL

Time Under Load (days)	0.0007 (1 min)	1 (1 day)	7 (1 week)	14 (2 weeks)	30 (1 month)	60 (2 months)	90 (3 months)
Total Deflection (in.)	0.723	0.780	0.824	0.842	0.859	0.871	0.880
Creep Rate (in./month)					0.136	0.012	0.009
Fractional Deflection	1.00	1.08	1.14	1.16	1.19	1.20	1.22

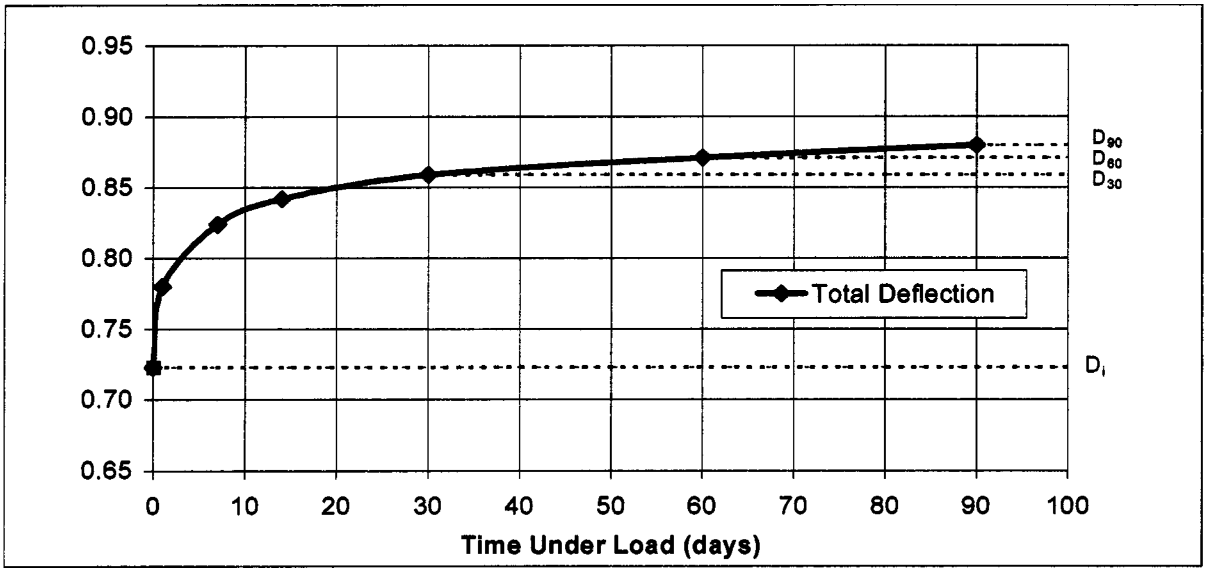


FIG. X2.1 Plot of LVL Total Deflection versus Time

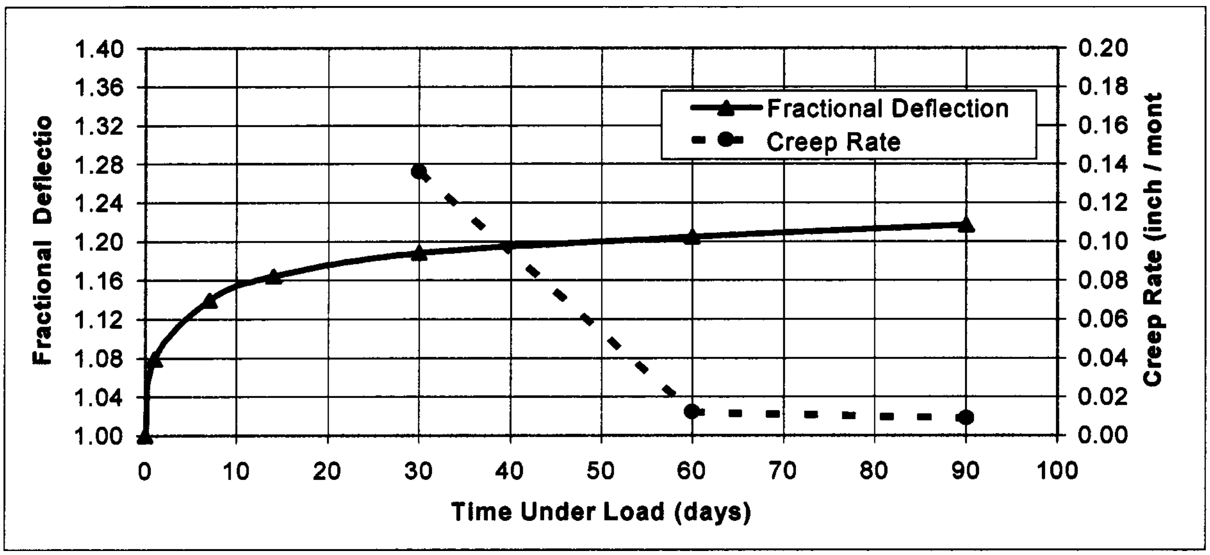


FIG. X2.2 Plot of LVL Fractional Deflection and Creep Rate

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