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Standard Specification for Evaluation of Structural Composite Lumber Products[1]

This standard is issued under the fixed designation D5456; 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.

ε[1] NOTE—Editorial corrections were made in July 2017.

INTRODUCTION

Structural composite lumber is intended for use as an engineering material for a variety of end-use applications. The composition of the lumber varies by wood species, adhesive composition, wood element size, shape, and arrangement. To provide the intended performance, composite lumber products require: (*1*) an evaluation of the mechanical and physical properties and their response to end-use environments, and (*2*) establishment of and conformance to standard performance specifications for quality.

Procedures contained in this specification are also to be used for establishing the design properties and for checking the effectiveness of property assignment and quality assurance procedures.

The quality assurance sections in this specification are intended to serve as a basis for designing quality-control programs specific to each product. The objective is to ensure that design values established in the qualification process are maintained.

This specification is arranged as follows:

1. Scope

1.1 This specification recognizes the complexity of structural glued products. Consequently, this specification covers both specific procedures and statements of intent that sampling and analysis must relate to the specific product.

1.2 This specification was developed in the light of currently manufactured products as defined in 3.2. Materials that do not conform to the definitions are beyond the scope of this specification. A brief discussion is found in Appendix X2.

1.3 Details of manufacturing procedures are beyond the scope of this specification.

NOTE 1—There is some potential for manufacturing variables to affect the properties of members that are loaded for sustained periods of time. Users of this specification are advised to consider the commentary on this topic in Appendix X2.

1.4 This specification primarily considers end use in dry service conditions, such as with most protected framing members, where the average equilibrium moisture content for solid-sawn lumber is less than 16 %. The conditioning environment of 6.3 is considered representative of such uses.

1.5 The performance of structural composite lumber is affected by wood species, wood element size and shape, and adhesive and production parameters. Therefore, products produced by each individual manufacturer shall be evaluated to determine their product properties, regardless of the similarity in characteristics to products produced by other manufacturers. Where a manufacturer produces product in more than one facility, each production facility shall be evaluated independently. For additional production facilities, any revisions to the full qualification program in accordance with this specification shall be approved by the independent qualifying agency.

1.6 This specification is intended to provide manufacturers, regulatory agencies, and end users with a means to evaluate a composite lumber product intended for use as a structural material.

[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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1.7 This specification covers initial qualification sampling, mechanical and physical tests, analysis, and design value assignments. Requirements for a quality-control program and cumulative evaluations are included to ensure maintenance of allowable design values for the product.

1.8 This specification, or parts thereof, shall be applicable to structural composite lumber portions of manufactured structural components.

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

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.11 *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]

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
C384 Test Method for Impedance and Absorption of Acoustical Materials by Impedance Tube Method
C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
D9 Terminology Relating to Wood and Wood-Based Products
D143 Test Methods for Small Clear Specimens of Timber
D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
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
D669 Test Method for Dissipation Factor and Permittivity Parallel with Laminations of Laminated Sheet and Plate Materials (Withdrawn 2012)[3]
D1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials
D1583 Test Method for Hydrogen Ion Concentration of Dry Adhesive Films
D1666 Test Methods for Conducting Machining Tests of Wood and Wood-Base Panel Materials
D1761 Test Methods for Mechanical Fasteners in Wood
D2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials
D2394 Test Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring
D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials
D2559 Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions
D2718 Test Methods for Structural Panels in Planar Shear (Rolling Shear)
D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
D3201 Test Method for Hygroscopic Properties of Fire-Retardant Wood and Wood-Based Products
D3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress
D4300 Test Methods for Ability of Adhesive Films to Support or Resist the Growth of Fungi
D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material
D4933 Guide for Moisture Conditioning of Wood and Wood-Based Materials
D5055 Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists
D5457 Specification for Computing Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design
D5764 Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood-Based Products
D6815 Specification for Evaluation of Duration of Load and Creep Effects of Wood and Wood-Based Products
D7247 Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures
D7480 Guide for Evaluating the Attributes of a Forest Management Plan
E84 Test Method for Surface Burning Characteristics of Building Materials
E96/E96M Test Methods for Water Vapor Transmission of Materials
E119 Test Methods for Fire Tests of Building Construction and Materials

2.2 *CSA Standards:*[4]

CSA Standards for Wood Adhesives O112-M Series
CSA O325 Construction Sheathing

2.3 *ISO/IEC Standards:*[5]

ISO/IEC 17020 General Criteria for the Operation of Various Types of Bodies Performing Inspection

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories
ISO/IEC 17065 Conformity Assessment – Requirements for Bodies Certifying Products, Processes and Services

2.4 *Other Standard:*
US Product Standard PS 2 Performance Standard for Wood-Based Structural-Use Panels

3. Terminology

3.1 *Definitions*—Standard definitions of wood terms are given in Terminology D9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Exposure 1 durability*—a bond classification for wood-based products that are not permanently exposed to the weather.

3.2.1.1 *Discussion*—Wood-based products classified as Exposure 1 are intended to resist the effects of moisture on structural performance due to construction delays or other conditions of similar severity.

3.2.2 *structural composite lumber (SCL)*—in this specification, structural composite lumber (SCL) is any of laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL), oriented strand lumber (OSL), or laminated veneer bamboo (LVB), which are intended for structural use and bonded with an exterior adhesive.

3.2.2.1 *laminated strand lumber (LSL)*—a composite of wood strand elements with wood fibers primarily oriented along the longitudinal axis of the member, where the least dimension of the wood strand elements is 0.10 in. (2.54 mm) or less and their average lengths are a minimum of 150 times the least dimension of the wood strand elements.

3.2.2.2 *laminated veneer bamboo (LVB)*—a composite of bamboo strand elements, edge-bonded to form veneer sheets which are then face-bonded to form finished products, with bamboo fibers primarily oriented along the longitudinal axis of the member where the least dimension of strand elements is 0.25 in. (6.4 mm) or less and their average strand lengths are a minimum of 300 times the least dimension of the bamboo strand elements (see X2.2).

3.2.2.3 *laminated veneer lumber (LVL)*—a composite of wood veneer sheet elements with wood fibers primarily oriented along the longitudinal axis of the member, where the veneer element thicknesses are 0.25 in. (6.4 mm) or less.

3.2.2.4 *oriented strand lumber (OSL)*—a composite of wood strand elements with wood fibers primarily oriented along the longitudinal axis of the member, where the least dimension of the wood strand elements is 0.10 in. (2.54 mm) or less and their average lengths are a minimum of 75 times the least dimension of the wood strand elements.

3.2.2.5 *parallel strand lumber (PSL)*—a composite of wood veneer strand elements with wood fibers primarily oriented along the longitudinal axis of the member, where the least dimension of wood veneer strand elements is 0.25 in. (6.4 mm) or less and their average lengths are a minimum of 300 times the least dimension of the wood veneer strand elements.

3.2.3 *Discussion*—SCL has three mutually perpendicular directions of orientation (see Fig. 1):

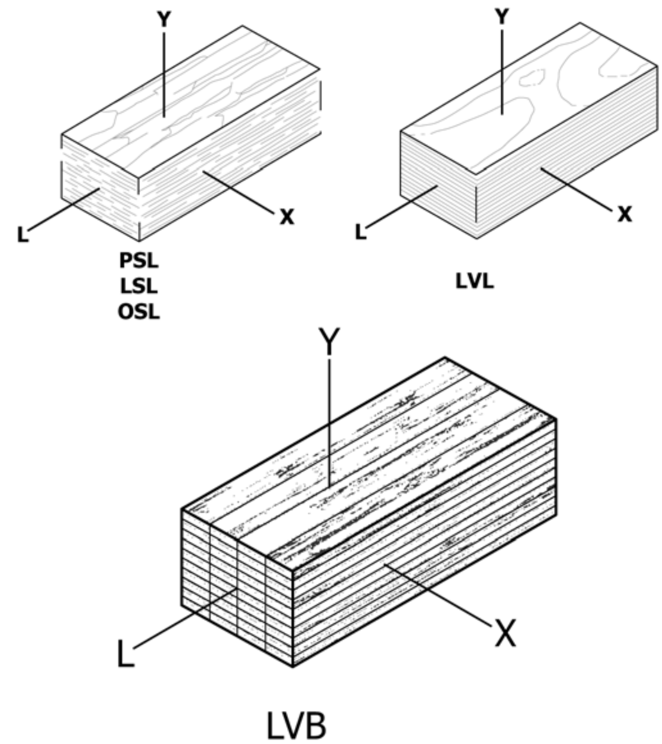


FIG. 1 Orientations for Structural Composite Lumber

L Direction—Parallel to the longitudinal direction of the member.
X Direction—Parallel to a surface of the member and normal to the *L* direction.
Y Direction—Normal to both *L* and *X* direction.

In this specification, longitudinal shear means shear stress in the *L-X* and *L-Y* planes. Planar shear is stress in the *X-Y* plane.

3.2.4 *SCL adhesive, n*—a material used for adhesion in the manufacturing of SCL products, which could be an SCL binder or non-binder adhesive.

3.2.5 *SCL binder adhesive, n*—an adhesive that bonds wood elements, such as flakes, strands, particles, or fibers, of SCL products and usually does not form a continuous bondline.

3.2.5.1 *Discussion*—Current examples of SCL binders include those systems used in the production of LSL and OSL.

3.2.6 *SCL non-binder adhesive, n*—an adhesive that bonds wood elements, such as veneers and veneer strand elements, of SCL products that is intended to completely cover all of the gluing surfaces.

3.2.6.1 *Discussion*—Current examples of SCL non-binder adhesives include those systems used in the production of LVL, PSL and LVB.

4. Materials

4.1 *General*—Structural composite lumber materials conforming to this specification meet the definition of a bio-based product in accordance with 3.3.1 of Guide D7480.

4.2 *Wood Elements*—Wood elements used in the fabrication of SCL products shall conform to 3.2.

4.3 *Adhesives*

4.3.1 *Non-Binder Adhesives*—Non-binder adhesives used in the fabrication of SCL products shall conform to the requirements in Specification D2559. In Canada, non-binder adhesives shall conform to the appropriate section of CSA Standards for Wood Adhesives, O112-M Series, except that the LVB adhesives shall be based on the criteria for hardwood species.

4.3.2 *Binder Adhesive*—Binder adhesives, when used, shall be evaluated to meet the requirements specifed in Annex A5 (see Note 2).

NOTE 2—Annex A5 requirements meet or exceed the requirements for Exposure 1; other conditions are beyond the scope of this specification. See the commentary and the section on Design and Mechanical Property Concerns in Appendix X2 for further information.

4.3.3 *Non-Binder and Binder Adhesives*—All adhesives used for SCL shall be qualified for heat durability performance in accordance with 4.3.4. X2.2.4 provides additional information.

NOTE 3—Heat durable performance implies that the bond between wood elements will permit the SCL to exhibit similar performance characteristics as solid wood in an elevated temperature environment.

4.3.4 *Adhesive Heat Durability:*

4.3.4.1 Adhesives used for LVL and PSL shall be qualified for heat durability performance through testing in accordance with Test Method D7247. The test temperature and heat exposure duration for specimens tested at elevated temperature (Section 7.2 of Test Method D7247) shall meet the requirements of Items *(1)*, *(2)*, *(3)*, and *(4)* below.

(1) The solid wood control specimens and bonded specimens shall be prepared from the same wood species of either Douglas Fir, Southern Pine, or the predominate species used in the LVL or PSL product, provided the same adhesive formulation is used for these wood species.

(2) For the bonded specimens, the minimum target bondline temperature shall be 428°F (220°C). For the matched solid wood control specimens, the minimum target temperature at the shear plane shall be 428°F (220°C).

(3) The minimum target temperatures of Item *(1)* shall be maintained for a minimum of 10 min or until achieving a residual strength ratio for the solid wood control specimens of 30 ± 10 %, whichever is longer.

(4) Block shear testing shall be conducted immediately after removal from the oven such that the specimen bondline or shear plane temperature does not drop more than 9°F (5°C) after leaving the oven and prior to failure. This provision is satisfied when the time interval from the removal of the specimen from the oven to the failure of the block shear specimen does not exceed 60 s for each specimen tested and the room temperature of the test laboratory at the time of testing is not less than 60°F (15.5°C).

4.3.4.2 The adhesive used for LSL and OSL shall be qualified for heat durability performance through testing in accordance with Test Method D7247 except that homogeneous pieces of LSL or OSL product shall be used in lieu of solid sawn face bonded specimens. The solid wood control species, LSL or OSL grade, test orientation of LSL and OSL, test temperature and heat exposure duration for specimens tested at elevated temperature (Section 7.2 of Test Method D7247) shall meet the requirements of Items (*1*), (*2*), (*3*), (*4*), (*5*), and (*6*) below.

(1) The solid wood control specimens shall be: Douglas Fir, Southern Pine, or the predominate species used in the LSL or OSL product. Each piece of solid wood used as part of this test method shall have a specific gravity equal to or exceeding the value specified in the National Design Specification.

(2) The highest grade of the LSL or OSL products shall be tested.

(3) The LSL and OSL specimen shear tests shall be conducted in the L-X plane and shall be loaded parallel to the wood grain or strands.

(4) For the LSL and OSL specimens, the minimum target bondline or shear plane temperature shall be 428°F (220°C). For the solid wood control specimens, the minimum target temperature at the shear plane shall be 428°F (220°C).

(5) The minimum target temperatures of Item (*4*) shall be maintained for a minimum of 10 min or until achieving a residual strength ratio for the solid wood control specimens of 30 ± 10 %, whichever is longer.

(6) Block shear testing shall be conducted immediately after removal from the oven such that the specimen bondline or shear plane temperature does not drop more than 9°F (5°C) after leaving the oven and prior to failure. This provision is satisfied when the time interval from the removal of the specimen from the oven to the failure of the block shear specimen does not exceed 60 s for each specimen tested and the room temperature of the test laboratory at the time of testing is not less than 60°F (15.5°C).

4.3.4.3 For adhesives tested in accordance with 4.3.4.1 and 4.3.4.2, the residual shear strength ratio for the bonded specimens, as calculated in accordance with Test Method D7247, shall be equal to or higher than the lower 95 % confidence interval on the mean residual shear strength ratio for the solid wood control specimens.

NOTE 4—The ability of the acceptance criteria to detect a heat-sensitive binder system may depend on the strand thickness or strand alignment, or both. Additional consideration may be warranted for products with large strand thickness or strands that are substantially not aligned with the test specimen shear plane, or both.

5. Mechanical Properties

5.1 The characteristic value for SCL is a statistic derived from test data as specified in 7.1. For bending and tension parallel to grain, the characteristic value is obtained at the unit volume as specified in 6.5.1 and 6.5.2.

5.2 The design stress related to SCL is derived from the characteristic value through application of the adjustments listed in Table 1 of this specification.

5.3 The allowable design stress published for engineering use shall be derived from the design stress modified by factors given in 7.3.

6. Qualification

6.1 Samples for qualification testing shall be representative of the population being evaluated. When an intentional modification to the process results in a reduction in mechanical

TABLE 1 Adjustment Factors

NOTE 1—Neither apparent modulus of elasticity nor compression strength perpendicular to grain is subject to load duration adjustments. All other factors are the product of 1.62, that adjusts data to normal duration as defined in 7.3.1 of Practice D245, and an additional factor for uncertainty (see Appendix X4 for an explanation of the shear block test adjustment factor).

Property	Adjustment Factor
Apparent modulus of elasticity	1.00
Bending strength	2.10
Tensile strength parallel to grain	2.10
Compressive strength parallel to grain	1.90
Longitudinal shear strength	
Shear block test	3.15
Structural-size shear test	2.10
Compressive strength perpendicular to grain	
Load applied normal to *L-Y* plane	1.67
Load applied normal to *L-X* plane	1.00

properties as indicated by the quality-control program, then new qualification is required.

6.1.1 Qualification tests shall be conducted or witnessed by a qualified agency in accordance with 8.1. All test results are to be certified by the qualified agency.

6.2 Sampling of the test material shall be done in accordance with applicable portions of the section on Statistical Methodology of Practice D2915.

6.2.1 Design stress, except for compression perpendicular to grain and apparent modulus of elasticity, shall be based on the 5^{th} percentile tolerance limit.

6.2.2 The confidence level for calculating tolerance limits and confidence intervals shall be 75 %.

6.2.3 Minimum sample size for calculating tolerance limits on 5^{th} percentiles shall be 53. When volume effect tests are made at multiple sizes for bending and tension, the minimum sample shall be 78 specimens at the unit volume specimen size.

6.2.3.1 The calculated 5^{th} percentile parametric tolerance limits (PTL) shall have a standard error no greater than 5 % of the PTL, when evaluated in accordance with 4.4.3.2 of Practice D2915. When necessary, the sample shall be increased beyond the minimum of 53, to meet this requirement.

6.2.4 Minimum unit sample sizes for compression perpendicular to grain (see 6.5.4) shall provide estimation of mean values within 5 % in accordance with 4.4.2 of Practice D2915. Minimum sample size shall not be less than 30.

6.3 Composite lumber used in qualification testing shall be brought to moisture equilibrium in a conditioned environment of 68 ± 11°F (20 ± 6°C) and 65 % (±5 %) relative humidity. Methods for determination of completion of conditioning are given in Guide D4933.

6.4 Moisture content and specific gravity shall be measured and reported for each specimen tested in the qualification program. Measurement for moisture content shall be in accordance with Test Methods D4442 and measurement of specific gravity shall be in accordance with Test Methods D2395.

6.5 *Mechanical Properties*—The properties that shall be evaluated by qualification testing shall include, but are not limited to: bending strength and stiffness, tensile strength parallel to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, and longitudinal shear strength.

6.5.1 *Bending*—Modulus of rupture and apparent modulus of elasticity shall be determined for both flatwise and edgewise bending in accordance with principles of Test Methods D198 or D4761. Specimen cross section shall not be less than the minimum anticipated structural size. Selection of specimen dimensions establishes the unit volume for the analysis of 7.4.1. Loading at third points and a span-to-depth ratio in the range from 17 to 21 shall be used for flatwise and edgewise bending.

NOTE 5—A span-to-depth ratio of 18 is a frequent international standard.

6.5.1.1 When either or both the size and moisture content of the qualification specimens will differ from specimens to be tested in quality control, the bending tests of 6.5.1 shall also be conducted on specimens of the size and the moisture content that will prevail at the time of routine quality-control testing. The specimens representing the quality-control conditions shall be matched with those to be conditioned (see 6.3). The ratio of the means of both strength and stiffness shall be used to adjust quality-control test results to the qualification level, for use in the confirmation required in 10.6.1.

6.5.1.2 Moisture content is recognized as different when the discrepancy between the average of the two test sets is one percentage point of moisture content or more. Sample size shall be the same for both test sets and not less than 78.

6.5.1.3 If testing is required in accordance with 6.5.1.1, the coefficient of variation of the bending strength from those tests shall be the basis for comparison required in 10.6.3. Otherwise, the coefficient of variation of the bending strength from the tests in 6.5.1 shall be the basis.

6.5.2 *Tension Parallel to Grain*—Tension strength parallel to grain shall be tested in accordance with principles of Test Methods D198 or D4761. Specimen cross section shall not be less than the minimum anticipated structural size. Specimen length shall provide for a minimum length of 36 in. (915 mm) between grips. Selection of specimen dimensions establishes the unit volume for the analysis of 7.4.1.

6.5.2.1 When either or both the size and moisture content of the qualification specimens will differ from specimens to be tested in quality control, the tension tests of 6.5.2 shall also be conducted on specimens of the size and the moisture content that will prevail at the time of routine quality-control testing. The specimens representing the quality-control conditions shall be matched with those to be conditioned (see 6.3). The ratio of the means of strength shall be used to adjust quality-control test results to the qualification level, for use in the confirmation required in 10.6.1. Moisture content is recognized as different when the discrepancy between the average of the two test sets is one percentage point of moisture content or more. Sample size shall be the same for both test sets and not less than 78.

6.5.2.2 If testing is required in accordance with 6.5.2.1, the coefficient of variation of the tensile strength from those tests shall be the basis for comparison required in 10.6.3. Otherwise, the coefficient of variation of the tensile strength from the tests in 6.5.2 shall be the basis.

6.5.3 *Compression Parallel to Grain*—Short-column compression strength parallel to grain shall be determined in accordance with principles of Test Methods D198 or D4761. Minimum cross section shall be 1.5 by 1.5 in. (38 by 38 mm). Length of the specimen shall be such that L/r is less than 17 and greater than 15, where L is the effective unsupported length and r is the least radius of gyration.

6.5.4 *Compression Perpendicular to Grain*—Compressive strength perpendicular to grain shall be determined in accordance with principles of Test Methods D143 except that references to placement of growth rings are not applicable and the dimension in the Y direction (see Fig. 1) is permitted to be a minimum of 1.5 in. (38 mm). The dimension in the X direction shall be 2.0 in. (51 mm). Testing shall be conducted with load applied normal to the L-Y plane in one test series and to the L-X plane in another series. Stress at both 0.02 and 0.04-in. (0.5 and 1.0-mm) deformation shall be reported. For load applied normal to the L-X plane, the proportional limit stress determined in accordance with 6.5.4.1 shall also be reported.

6.5.4.1 *Proportional Limit Stress*—The proportional limit stress shall be calculated from the proportional limit load defined as the load at which the load-deformation curve deviates from a linear regression fitted to the approximately linear portion of the load-deformation curve.

$$\sigma_{PL} = P_{PL}/(l_p\, b) \tag{1}$$

where:

σ_{PL} = proportional limit stress,
P_{PL} = proportional limit load,
l_p = measured length of bearing plate parallel to specimen length (L-direction), and
b = measured width of specimen (X-direction).

NOTE 6—The proportional limit stress can also be determined from a stress-strain curve derived from the load-deformation curve.

6.5.5 *Longitudinal Shear*—Longitudinal shear strength in the L-Y plane shall be determined by conducting ASTM block shear tests or structural-size horizontal shear tests. Longitudinal shear strength in the L-X plane shall be determined by conducting ASTM block shear tests. When evaluating the effect of systematic manufacturing characteristics that might affect horizontal shear strength, the structural size horizontal shear test method shall be used (see Annex A3).

6.5.5.1 ASTM block shear tests shall be conducted in accordance with principles of Test Methods D143 except that a minimum dimension of 1.5 in. (38 mm) at the shear area is acceptable provided that the total shear area is 4 in.^{2} (2580 mm^2).

6.5.5.2 Structural-size horizontal shear tests in the L-Y plane shall be conducted in accordance with the procedures specified in Annex A3 of this specification.

6.5.5.3 If anticipated end use involves shear perpendicular to grain on a face of the material (planar shear), testing shall establish allowable shear stress in accordance with the principles of Test Method D2718.

6.6 *Connections*—Determination of allowable design values for withdrawal capacities of nails, and dowel-bearing capacities of bolts, lag screws, wood screws, and nails is specified in Annex A2. Determination of allowable design values for other connectors is beyond the scope of this specification.

6.7 *Shear Modulus*—Shear modulus (G) for LVB shall be determined and reported in accordance with Test Methods D198. The shear deformation shall be considered in the total deflection calculation.

6.8 *Bond Quality:*

6.8.1 *Internal Bond*—For bond quality evaluation of PSL, LSL, and OSL, internal bond shall be tested and reported in accordance with Test Methods D1037 (see Note 8), except that the tests shall be done at a constant rate of displacement such that the average time-to-failure is not less than 1 min. The minimum sample size shall not be less than 50 test specimens taken from multiple cross-sections and locations.

6.8.2 For LVL, the glue bond quality shall be evaluated in accordance with 6.5.5 in the L-X plane except that the percentage of wood failure shall be evaluated and reported.

NOTE 7—A4.2 provides an adhesive durability test method that a manufacturer may use as a means to evaluate bond durability for quality assurance or product optimization. However, A4.2 is not intended for adhesive qualification testing as required in Annex A5.

6.8.3 For LVB, the glue bond quality shall be evaluated in accordance with 6.5.5 in the L-X and L-Y planes except that the percentage of fiber failure shall be evaluated and reported.

6.9 *Product Durability:*

6.9.1 *Edgewise Bending Durability*—For all SCL products, edgewise bending durability shall be conducted in accordance with A4.3. The average strength retention shall be at least 75 %.

6.9.2 *Lateral Edge Nail Durability*—For PSL, LSL, OSL, and LVB, lateral edge (X-L) nail durability shall be evaluated in accordance with A4.4. The average strength retention shall be at least 75 %.

6.10 *Physical Properties:*

6.10.1 *Thickness Swell*—For PSL, LSL, OSL, and LVB, thickness swell shall be tested and reported in accordance with Test Methods D1037 (see Note 8). The minimum sample size shall not be less than 25 test specimens taken from multiple cross-sections and locations.

NOTE 8—Test Methods D1037 specifies that the test thickness shall be that of the finished board. Some SCL products are manufactured in thicknesses greater than those intended for evaluation by the procedures in Test Methods D1037. It may be necessary to limit the test thickness for PSL products that are manufactured in thicknesses greater than 3.5 in. (89 mm).

6.10.2 *Density Gradient Through the Thickness*—For LSL and OSL, density gradient through the thickness shall be tested and reported in accordance with A4.5.

6.10.3 *Other Physical Properties*—Other physical properties shall be assessed when they affect end use. Information on other physical properties and related standards is given in Appendix X2.

7. Determination of Allowable Design Stresses

7.1 Allowable design values developed in this section are consistent with engineering practice in building construction.

Their applicability in other types of structures has not been evaluated and such applications require independent evaluation.

7.2 *Characteristic Value*—In the derivation of the characteristic value, the procedures in the sections on Statistical Methodology and Analysis and Presentation of Results of Practice D2915 shall be followed, except that provisions of this specification govern where differences occur.

7.2.1 The 5th percentile tolerance limit (TL) with 75 % confidence from test results of 6.5 shall be the characteristic value for strengths in flexure, tension parallel to grain, compression parallel to grain, and longitudinal shear.

7.2.1.1 Parametric or nonparametric analysis shall be performed to obtain a 5th percentile tolerance limit.

7.2.1.2 For parametric analysis either the normal or lognormal distribution shall be used to establish a 5th percentile tolerance limit with 75 % confidence. The distribution selection shall be based on standard statistical goodness of fit tests. As a minimum, the fit selection shall include visual inspection of cumulative frequency plots of the fitted distributions with the data and the lesser of standard errors of the estimate from the two distributions fitted by the method of least squares.

NOTE 9—Experience has shown that data from SCL typically has coefficients of variation (COV) less than 20 % and are symmetrical to slightly right skewed and, therefore, are reasonably described by the normal and lognormal distributions. Goodness of fit references are given in Note 6 of Practice D2915. The minimum procedures of 7.2.1.2 are detailed in X4.7 of Specification D5055.

7.2.2 The average value for apparent modulus of elasticity from test results of 6.5.1 shall be the characteristic value for apparent modulus of elasticity.

7.2.3 *Compression Perpendicular to Grain:*

7.2.3.1 *Compression Perpendicular to L-Y Plane*—The average stress at 0.04-in. (1.0-mm) deformation for compression perpendicular to grain from test results of 6.5.4 shall be the characteristic value for compression perpendicular to the *L-Y* plane.

7.2.3.2 *Compression Perpendicular to L-X Plane*—The lower of the average stress at 0.04-in. (1.0-mm) deformation or the average stress at the proportional limit from the test results of 6.5.4 shall be the characteristic value for compression perpendicular to the *L-X* plane.

7.3 *Design Stresses*—Design stresses shall be calculated from the characteristic value defined in 7.2 in accordance with the following formula:

$$S = \frac{B}{C_a} \tag{2}$$

where:

S = design stress,
B = characteristic value, and
C_a = adjustment factor from Table 1.

7.4 *Allowable Design Stress*—Design stresses shall be modified by factors that consider the end-use applications as follows:

$$F_a = C_e S \tag{3}$$

where:

F_a = allowable design stress,
C_e = product of end use (K) factors, and
S = design stress.

Factors common to all members are detailed in this section.

7.4.1 *Volume Factors:*

7.4.1.1 Strength properties are affected by the relative volume at a given stress. For purposes of this section, the members tested in edge bending or axial tension in Section 6 shall be taken as a unit volume. Sections other than solid rectangles, or solid rectangular sections not loaded axially or normal to one of its surfaces, require special investigation.

7.4.1.2 Volume factors shall either be determined from the prescribed theoretical relationships or by testing on a range of sizes, as detailed in Annex A1.

7.4.1.3 *Bending*—Bending design stress shall be adjusted for volume effect by multiplication with the factor as follows:

$$K_d = \left(\frac{d_1}{d}\right)^{2/m} = \left(\frac{d_1}{d}\right)^{1/n} \tag{4}$$

where:

K_d = factor applied to design stress of the member of unit volume,
d_1 = depth of unit volume members,
d = depth of an application member,
m = a parameter determined in accordance with Annex A1, and
n = $m/2$

NOTE 10—A derivation of Eq 4 is given in Ref **(1)**[6] along with example data. In this case, volume considered is only two-dimensional since, at least within the limits given in Annex A1, increasing width of SCL bending members does not result in strength reduction. In some cases, tests show a strength increase with increasing width, possibly because of greater stability along the compression edge. Therefore the two-dimensional form of the equation is of the form $K_d = (d_1/d)^{1/m} (L_1/L)^{1/m}$ where L_1 and L are the length of the unit volume and application member, respectively. When a constant span/depth ratio is assumed, Eq 4 becomes $K_d = (d_1/d)^{2/m}$, which can be further simplified to $K_d = (d_1/d)^{1/n}$, where $n = m/2$.

7.4.1.4 *Axial Tension*—Tensile design stress shall be adjusted for volume by multiplication with factor as follows:

$$K_L = \left(\frac{L_1}{L}\right)^{1/m} \tag{5}$$

where:

K_L = adjustment factor,
L_1 = base length between grips tested in 6.5.2,
L = end-use length, and
m = parameter determined in accordance with Annex A1.

NOTE 11—Tension tests of SCL do not show strength reductions for increasing cross section so that volume is represented by length alone. Annex A1 states criteria for accepting this approach without limitations. Ref **(1)** gives example data.

7.4.1.5 When volume effect factors are based on single-size testing in accordance with A1.2.3, increased design stresses for members smaller than that tested are not permitted.

7.4.1.6 Other related conditions that influence the bending strength of a member include the loading diagram and support

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

condition. Adjustments for common load cases are given in Annex A1 and other information is found in Ref (**2**).

7.4.2 *Duration of Load/Creep Effects:*

7.4.2.1 Duration of load and creep effects shall be evaluated in accordance with Specification D6815. As a minimum, one representative grade per adhesive classification shall be evaluated. It is the responsibility of the manufacturer and the certified agency to determine which representative grade and what species or species combination shall be evaluated by considering the density and gluing characteristics of the species or species combination. Chapter 9 of the Wood Handbook (**3**) provides additional guidance.

NOTE 12—For products manufactured with one or more species, either separately or mixed, the greatest anticipated percentage(s) of the highest density species should be evaluated (see Appendix X2).

7.4.2.2 The allowable design stresses developed in this specification correspond to the condition of normal loading as defined in 7.3 of Practice D245 provided the product demonstrates acceptable long-term load performance as determined in accordance with Specification D6815. These stresses shall be adjusted for other loading durations using the same factors applied to sawn lumber and other wood and wood-based structural members, as defined in Ref (**4**).

7.4.3 Allowable design stresses developed in this specification are for use in dry conditions as defined in 1.4. If use at other moisture conditions is intended, a documented test-based investigation leading to appropriate properties adjustment must be carried out.

7.4.4 *Other End-Use Adjustments*—In some cases, end use requires other adjustments. A brief discussion of such use conditions is given in Appendix X2.

7.5 To convert allowable design stresses to load and resistance factor design (LRFD) format, use the procedures of Specification D5457.

8. Independent Inspection

8.1 A qualified agency shall be employed by the manufacturer to audit the quality assurance program and inspect the production process of the plant without prior notification or with minimal prior notification. The audit and inspection shall include review and approval of the plant's quality assurance program and inspection of randomly selected products and QC data. When production is sporadic, the qualified agency shall communicate with the manufacturer to schedule inspections to coincide with production.

8.2 *Qualified Agency*—A qualified agency is defined to be one that:

8.2.1 Has been accredited by an International Accreditation Forum (IAF) member accreditor as meeting ISO/IEC 17020 requirements;

8.2.2 Has access to the facilities and trained technical personnel to verify that the grading, measuring, species, construction, bonding, workmanship, and other characteristics of the products as determined by inspection, sampling, and testing comply with all applicable requirements specified in this specification;

8.2.3 Has procedures to be followed by its personnel in performance of the inspection and testing;

8.2.4 Has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being inspected or tested; and

8.2.5 Is not owned, operated, or controlled by any such company.

9. Manufacturing Standard

9.1 A manufacturing standard, subject to the approval of the qualified agency, shall be written and maintained by the manufacturer for each product and each production facility. This specification shall include provision for quality assurance.

10. Quality Assurance

10.1 *Quality Assurance in Manufacturing Standard*—This portion of the manufacturing standard shall include subject matter necessary to the quality-assurance program including the following:

10.1.1 Material specifications, including incoming material inspection and acceptance requirements, and

10.1.2 Quality assurance, inspection, testing, and acceptance procedures.

10.1.2.1 Sampling and inspection frequencies shall be devised to encompass all variables that affect the quality of the finished product. Increased frequencies shall be used in connection with new or revised facilities. A random sampling scheme shall generally be used for specimen selection.

NOTE 13—Increased sampling and test frequency is a useful procedure when investigating apparent data trends or adjustments in the process. It is desirable at times to deviate from a random sampling scheme while investigating effects of specific variables.

10.1.3 Procedures to be followed upon failure to meet specifications or upon out-of-control conditions shall be specified. Included shall be reexamination criteria for suspect material and material rejection criteria.

10.1.4 Finished product marking, handling, protection, and shipping requirements as they relate to the performance quality of the product shall be defined.

10.2 *Inspection Personnel*—All manufacturing personnel responsible for quality control shall demonstrate to the qualified agency that they have knowledge of the inspection and test procedures used to control the process of the operation and calibration of the recording and test equipment used and of the maintenance and interpretation of quality-control records.

10.2.1 Use of quality-control records beyond quality control, for monitoring and adjusting allowable design values, requires special recognition. The independent inspection agency and manufacturing quality-control personnel must maintain continuing awareness of this additional responsibility.

10.3 *Record Keeping*—All pertinent records shall be maintained on a current basis and be available for review by the qualified agency personnel. As a minimum, such records shall include:

10.3.1 All inspection reports and records of test equipment calibration, including identification of personnel carrying out the tests;

10.3.2 All test data, including retests and data associated with rejected production; and

10.3.3 Details of any corrective actions taken and the disposition of any rejected production resulting from tests or inspections.

10.4 *Quality Assurance Testing:*

10.4.1 *Testing Equipment*—Testing equipment is to be properly maintained, calibrated, and evaluated for accuracy and adequacy at a frequency satisfactory to the qualified agency.

10.4.2 *Required Tests*—The following shall be considered to be the scope of a minimum testing program:

10.4.2.1 The bending test described in 6.5.1 shall be used for quality assurance of bending strength and stiffness.

10.4.2.2 The tension test described in 6.5.2 shall be used for quality assurance of tensile strength parallel to grain.

10.4.2.3 Moisture content data shall be determined by the same process as in 6.4, at a frequency that provides a representative sample of production.

10.4.2.4 Bond quality, product durability, and physical property tests described in 6.8.1, 6.9.1, 6.10.1, and 6.10.2 shall be used for quality assurance when applicable.

10.4.2.5 When required, quality assurance data shall be adjusted by the factors of 6.5.1.1 and 6.5.2.1 prior to further analysis.

10.4.2.6 Test frequency for all tests shall be chosen to yield quality-assurance performance that is consistent with design stresses assigned to the product and its intended use.

10.5 *Process Control:*

10.5.1 Prior to shipping material represented by the Q.A. sample, data from the tests of 10.4 shall be evaluated to confirm that the material properties are in statistical control. The control level selected shall be consistent with current design values and intended use of the material. For PSL, LSL, and OSL, internal bond quality in accordance with 6.8.1 shall also be evaluated prior to shipping material.

NOTE 14—References **(5-7)** provide useful background material on quality control.

10.5.2 When the analysis of 10.5.1 indicates that the material properties are below the control level, the associated portion of production shall be subject to reexamination in accordance with acceptance procedures of 10.1.3.

10.6 *Cumulative Evaluation:*

10.6.1 *Design Stresses*—Periodically, characteristic values and associated allowable stress values shall be formally checked using data accumulated in 10.4. At least one such check shall be made in the first six months of operation involving new production or from any new product line. Thereafter, analysis shall be conducted at intervals not to exceed one year.

10.6.2 *Analysis*—The periodic analysis shall be conducted in accordance with 7.1 – 7.3. All data from the period associated with statistical process control shall be included in the analysis.

10.6.2.1 Design values must be affirmed by the analysis of 10.6.2 or be reduced accordingly.

10.6.2.2 When design values have been reduced in accordance with 10.6.2.1 or at the option of the producer because of excessive reject rates, a new statistical process control level in keeping with the new design value shall be established. The evaluation then includes all data from the period in statistical control based upon the new control level.

10.6.3 *Volume Effect*—If the coefficient of variation of bending strength, as computed directly from data analysis in 10.6.2, has increased by one and one-half percentage points or more over corresponding values determined in 6.5.1 or 6.5.2, the parameter (m) in Eq 4 and Eq 5 shall be recomputed using Eq A1.1.

11. Keywords

11.1 accelerated aging; allowable design stresses; binder; durability; mechanical properties; non-binder; quality assurance; structural composite lumber

ANNEXES

(Mandatory Information)

A1. VOLUME EFFECT PARAMETER DETERMINATION

A1.1 Scope

A1.1.1 Annex A1 covers procedures that shall be used to determine the exponent in Eq 4 and Eq 5. Sections A1.2 and A1.3 define, for bending and tension respectively, the value of the exponent for single-size test data and the sampling procedures for multiple size testing. Section A1.4 gives a uniform procedure for processing multiple-size test data to determine the exponent for both bending and tension, experimentally.

A1.1.2 Limits on extrapolation beyond test data are given in A1.2.2 and apply to either single or multiple size specimen tests. Extrapolation beyond testing is not limited in tension, provided the requirements of A1.3.2 are met.

A1.2 Flexure

A1.2.1 If test data for only one specimen size are available as specified in 6.5.1 as a minimum requirement, the value of (*m*), Eq 4, 7.4.1.3, is given in A1.2.3 by specific formulation.

A1.2.2 Thicknesses greater than three times the maximum tested in 6.5.1 or A1.2.4 shall not be used in design without further tests incorporating greater thicknesses. Calculation of design stresses using the factor of Eq 4 shall be restricted to members not exceeding four times the volume (computed as length times depth) of the largest member tested.

A1.2.3 For single-size testing, the value of (*m*) is determined as follows:

$$m = C^{-1.08} \quad (A1.1)$$

where:

m = shape parameter of a two-parameter Weibull distribution, and
C = COV of the data with the restriction that if C < 0.15 then *m* = 8.

NOTE A1.1—At $C = 0.15$, $m \sim 8$ so that $2/m = 1/4$. Specification of a minimum threshold of 0.15 on *C* is a default level to encourage multiple-size testing. Eq A1.1 is an approximation that simplifies and avoids the use of the gamma function. It gives estimates of (*m*) accurate to 2 % for COV's in the range from 0.05 to 0.30.

A1.2.4 Minimum sampling for multiple-size testing requires a minimum of four depths, including the base depth specified in 6.5.1, with sample sizes as specified in A1.2.5. The test range of volume (computed as length times depth) shall have a ratio of not less than 20 from the smallest depth to the largest piece. Span-to-depth ratios in all test series shall be the same and as selected in 6.5.1. From Eq 4:

$$K_d = \left(\frac{d_1}{d}\right)^{2/m} \quad (A1.2)$$

A1.2.5 Sample sizes below the base depth shall be 30 for each depth. Above the base depth the sample size, *N*, shall be determined by the following formula but not less than *N* = 5. Sample size for the base depth is given in 6.2:

$$N = 50\left(\frac{d_1}{d}\right) \quad (A1.3)$$

where:

d_1 = base depth tested in 6.5.1, and
d = any depth larger than base.

NOTE A1.2—The sample size equation is simple and judgmental. Experience on structural composite lumber has shown that test results from larger members are less variable. The expectation of lower variability for larger specimens in a weak link analysis can also be supported theoretically using a three-parameter Weibull distribution. The end result is a reduction of COV for larger sizes and an approximate maintenance of statistical precision with fewer samples.

A1.3 Tension

A1.3.1 If test data have been obtained for only one specimen size, as a minimum requirement in 6.5.2, the value of (*m*), Eq 5, 7.4.1.4, is given by specific formulation.

A1.3.2 Eq 5 is used for any tension member provided the exponent developed agrees with theory when compared to the bending exponent. Members of cross-sectional area greater than three times the maximum tested in 6.5.2 or A1.3.4 shall not be used in design without additional tests involving greater cross sections.

NOTE A1.3—If the coefficient of variation is identical in tension and bending, the Weibull shape parameter, (*m*), will be the same. With differing coefficients of variation, the expected difference in exponents can be predicted from Eq A1.1.

A1.3.3 For single-length testing, the value of (*m*) is determined with Eq A1.1 using the COV of the tensile test data, if greater than 0.15, otherwise, *m* = 8.

A1.3.4 For multiple-length testing, minimum sampling requires four lengths, including the base length, with sample sizes as specified in A1.3.5. Minimum gage length (distance between grips) shall be 2 ft (610 mm) with the maximum gage length equal to or exceeding five times the minimum.

A1.3.5 Sample sizes below the base length shall be 30 for each length. Above the base length minimum sample sizes, *N*, shall be determined by the following formula with the constraint that *N* shall not be less than 20.

$$N = 50\sqrt{\frac{L_1}{L}} \quad (A1.4)$$

where:

L_1 = base gage length tested in 6.5.2, and
L = any length longer than the base.

A1.4 Exponents from Multiple-Size Tests

A1.4.1 Exponents for bending and tension are each calculated by two procedures. In each of the two cases an "empirical" exponent and a "theoretical" (*m*) are calculated. The relationships between empirical and theoretical values dictate a final choice for each case.

A1.4.2 The empirical procedure for a case requires logarithmic transformation of normalized average strengths and sizes and fitting a least squares line to these transformed data. The desired exponent for Eq A1.2 and Eq 5 is obtained by linear regression of transformed variables *x* and *y* with a forced zero intercept of the fitted line in the *x, y* space. Eq A1.2 and Eq 5 are written as follows:

$$K = \left(\frac{Z_0}{Z}\right)^q \quad (A1.5)$$

where:

q = 2/*m* or 1/*m*,
Z_0 = base depth or length, and
Z = test depth or length.

A1.4.2.1 The ratio (*K*) in Eq A1.5 is the strength modification factor and in the data:

$$K = (F/F_0) \quad (A1.6)$$

where:

F = average experimental strength for test size *Z*, and
F_0 = average experimental strength for base size Z_0.

A1.4.2.2 Then use common logarithms and set as follows:

$$\text{Log}\left(\frac{F}{F_0}\right) = q\,\text{Log}\left(\frac{Z_0}{Z}\right) \quad (A1.7)$$

that is in the following form:

$$y = qx \quad (A1.8)$$

A1.4.2.3 The empirical exponent ($q = 1/m$ or $2/m$) is obtained from the least squares computation as follows:

$$q = \frac{\sum xy}{\sum x^2} \quad (A1.9)$$

where summation is from the minimum through the maximum size tested.

A1.4.3 The theoretical procedure requires determination of the shape parameter, (m), of a two-parameter Weibull distribution fitted to the unit volume strength data. Tail fitting techniques, (an example is shown in Appendix X4 of Specification D5055), are also acceptable provided 75 or more data points are used and these points include at least the tenth-percentile experimental value. The theoretical exponent (Q) for Eq A1.2 or Eq 5 is $2/m$ or $1/m$ as determined in this procedure, for bending and tension respectively.

A1.4.4 The processes of A1.4.2 and A1.4.3 produce two curves of strength versus size for both bending and axial tension as follows:

$$F_1 = F_0\left(\frac{Z_0}{Z}\right)^q \quad (A1.10)$$

and

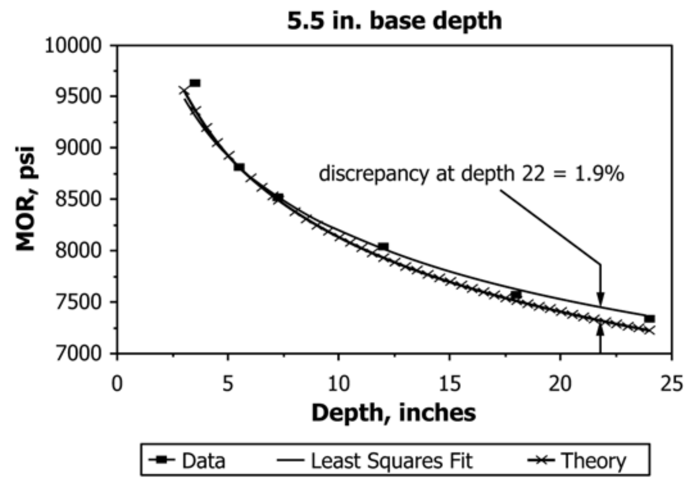
$$F_2 = F_0\left(\frac{Z_0}{Z}\right)^Q \quad (A1.11)$$

where:

q = is determined in A1.4.2, and
Q = is determined in A1.4.3.

A1.4.5 The curve fitted by the empirical procedure in A1.4.2 is acceptable for strength adjustment if (see Fig. A1.1 and Fig. A1.2):

A1.4.5.1 The theoretical curve of Eq A1.11 lies above the curve of Eq A1.10, or



NOTE 1—1 in. = 25.4 mm.

FIG. A1.1 Bending Volume Effect

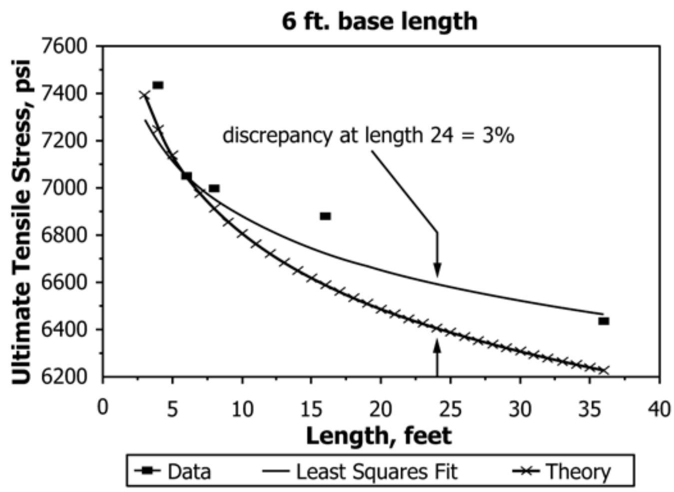
A1.4.5.2 The Eq A1.10 curve value at the greater of four times Z_0 or 20 in. (508 mm) for bending and at 20 ft (6.1 m) for tension is not more than 5 % above the Eq A1.11 curve value using the latter as the basis for percentage calculation.

A1.4.5.3 If conditions A1.4.5.1 or A1.4.5.2 are not met, a new (q) exponent shall be determined such that condition A1.4.5.2 is satisfied.

A1.4.6 The final exponent determined in A1.4.5 shall be rounded to two decimal places and used to adjust bending and tension design stresses for volume effect.

NOTE A1.4—The empirical exponent (q) developed for bending statistically estimates ($2/m$ or $1/n$).

A1.5 *Adjustment for Loading*—Adjustments of flexure stress for types of loading are given in Table A1.1. These values vary according to the COV of the base size data. The COV in Table A1.1 is an actual value unrelated to the special constraint on COV in A1.2.3 and A1.3.3 (the latter is an adjustment to cause size factors to be conservative when size effect has not been experimentally investigated).



NOTE 1—1 in. = 25.4 mm.

FIG. A1.2 Tensile Length Effect

TABLE A1.1 Flexure Stress Adjustment Factors for Loading Conditions

NOTE 1—Table A1.1 is developed from weak-link theory and accounts for variations in stress distribution along the length of the member (that is, differences in moment diagram) for common cases. For example, if allowable bending stress is developed from third-point loading tests, for uniform load the allowable increases by 1/0.96 and the adjustment to center-point load would be 1.13/0.96, for COV = 15 %. The table factors are independent of volume adjustments.

Loading Conditions for Simply Supported Beams	Adjustment Factor		
	COV = 0.10	COV = 0.15	COV = 0.20
Center-Point Load	1.10	1.13	1.16
Third-Point Loads	0.96	0.96	0.96
Uniform Load	1.00	1.00	1.00

A2. ESTABLISHING EQUIVALENT SAWN LUMBER SPECIES CONNECTION PROPERTIES FOR SCL

A2.1 Scope

A2.1.1 Annex A2 presents one method for establishing equivalency for connection properties between a species of SCL and a species combination of sawn lumber. The equivalency is limited to withdrawal capacities of nails and bearing capacities of dowel-type fasteners (bolts, lag screws, wood screws, and nails).

NOTE A2.1—The method presented in Annex A2 does not preclude the use of alternate methods of establishing equivalency of design values, such as direct comparative testing of joints.

A2.1.2 Equivalency is established by determining an equivalent specific gravity for an SCL product. The SCL equivalent specific gravity value is established by determining the specific gravity value of a solid sawn species or species combination in Ref (**4**) that shows equivalent nail withdrawal or dowel bearing performance. This SCL-equivalent specific gravity permits the design of connections in SCL using established design procedures and specific gravity values for species combinations of sawn lumber found in Ref (**4**).

A2.1.3 A different species combination equivalent specific gravity is permitted for fasteners installed in both the *X* and *Y* orientations (see Fig. 1) for both nail withdrawal and dowel bearing.

A2.2 Sample Size

A2.2.1 Minimum sample size for each test group shall provide 5 % precision of estimation of the mean value, with 75 % confidence, in accordance with 4.4.2 of Practice D2915. Minimum sample size shall not be less than ten.

A2.3 Test Specimen

A2.3.1 Specimens shall be selected in accordance with 6.1 and conditioned in accordance with 6.3. Moisture content and specific gravity shall be measured and reported in accordance with 6.4.

A2.3.2 The average specific gravity of the test specimens shall not exceed the average specific gravity of the bending specimens from 6.5.1 by more than 0.03.

A2.4 Withdrawal Tests

A2.4.1 Withdrawal testing shall be performed for the *Y* orientation. When design values for the *X* orientation are desired, testing shall also be performed with the fastener in the *X* orientation. Testing for single nails in withdrawal shall be conducted in accordance with Test Methods D1761.

A2.4.2 The withdrawal resistance in lb/in. (N/mm) of penetration of 0.131-in. (3.33-mm) diameter, 2.5-in. (64-mm) long (8d) steel common wire nails shall be determined. The nail penetration shall be based on the total penetration of the nail, including the point of the nail. The depth of penetration shall be a minimum of 1.25 in. (32 mm).

A2.5 Dowel Bearing Tests

A2.5.1 Testing for dowel bearing strength shall be conducted in accordance with Test Method D5764. Testing for bolts and nails installed in the *Y* orientation and loaded in both the *X* and *L* directions is required. Testing for nails or bolts installed in the *X* orientation and loaded in both the *Y* and the *L* directions is required for applications utilizing nails or bolts installed in the *X* orientation.

A2.5.2 Rate of testing is in accordance with Test Method D5764.

A2.5.3 Test configuration shall be in accordance with Test Method D5764.

NOTE A2.2—Test Method D5764 permits the use of either a half-hole or full-hole test configuration. The full hole test configuration as shown in Fig. A2.1 has been found to minimize specimen splitting that causes failure to occur prior to the point where the 5 % offset intersects the load-deformation curve ($P_{5\ \%\ off}$).

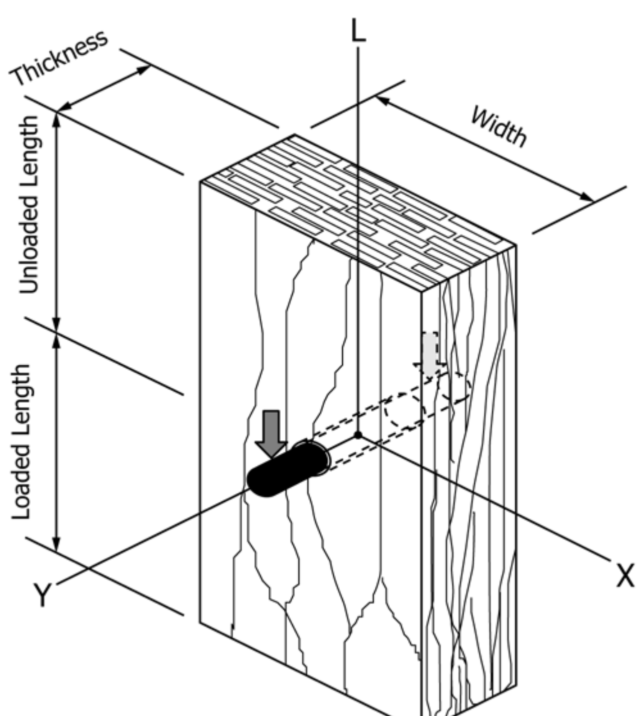


FIG. A2.1 Full Hole Test Configuration (Dowel in *Y* orientation, loaded in the *L* direction)

A2.5.4 Dowel bearing strength for one size of steel common wire nail shall be determined. Minimum size is 0.148 in. (3.76 mm) diameter, 3 in. (76 mm) long (10d common wire nail).

A2.5.5 The dowel bearing strength of ½-in. (12.7-mm) bolts and ¾-in. (19-mm) diameter bolts shall be determined. Bolt length shall be sufficient to prevent bearing on the threads in the specimen.

A2.6 Withdrawal Equivalence

A2.6.1 The equivalent specific gravity is determined from Table 11.2C of Ref (**4**) such that the table value for the tested nail does not exceed the average ultimate withdrawal resistance in lb/in. (N/mm) from A2.4 divided by 5.0. Straight line interpolation between the nearest withdrawal design values in Table 11.2C of Ref (**4**) is permitted to obtain a closer approximation of SCL-equivalent specific gravity.

A2.6.2 The specified testing establishes the equivalent specific gravity for the full range of nail types and sizes in Table 11.2C of Ref (**4**). A different species combination equivalent specific gravity is permitted for nails installed in the *X* and *Y* orientations. If one equivalent specific gravity is to be specified for both *Y* and *X* orientations then it shall be the lower of the two individual values.

NOTE A2.3—An example calculation is provided in Appendix X3.

A2.7 Dowel Bearing Equivalence

A2.7.1 *Nails:* The nail dowel bearing strength is determined by dividing $P_{5\%\ off}$ from A2.5 by the nail diameter and specimen dimension parallel to the nail length. The dowel bearing strength for nails installed in a specific orientation (either *X* or *Y*) shall combine the average of the test results from both loaded directions provided that they do not differ from the average of the test results from either of the loaded directions by more than 20 %. If the individual dowel bearing results for each orientation differ by more than 20 % from the combined average, then the dowel bearing strength shall be equal to the lower test value of both loaded directions divided by 0.8.

NOTE A2.4—$P_{5\%\ off}$ is the load at which a line parallel to the initial slope of the load-deformation curve and offset by an amount equal to 5 % of the dowel diameter, intersects the load-deformation curve or the maximum load, whichever occurs first.

A2.7.2 The equivalent specific gravity value for laterally loaded nails shall be determined from Table 11.3.2 of Ref (**4**) such that the table value of dowel bearing strength does not exceed the average dowel bearing strength from A2.7.1. The equations contained in the footnotes to Table 11.3.2 of Ref (**4**) can be used to obtain a closer approximation of SCL-equivalent specific gravity. If dowel bearing tests are conducted in both the *X* and *Y* orientations, then an equivalent specific gravity value shall be determined for each orientation. If one equivalent specific gravity is to be specified for both *Y* and *X* orientations then it shall be the lower of the two individual values.

A2.7.3 The results from the nail tests can also be applied to wood screws.

A2.7.4 *Bolts*—The equivalent specific gravity value for laterally loaded bolts shall be determined from Table 11.3.2 of Ref (**4**) such that the table value of dowel bearing strength does not exceed $P_{5\%\ off}$ from A2.5 divided by the bolt diameter and by the specimen dimension parallel to the bolt length. The equations contained in the footnotes to Table 11.3.2 of Ref (**4**) can be used to obtain a closer approximation of SCL-equivalent specific gravity.

A2.7.5 Equivalent specific gravity values for design use with bolts shall be the average of individual equivalent specific gravity values for all bolt diameters and load directions for a given orientation (*X* or *Y*) provided that they do not differ from the average of the test results by more than 0.03. If the individual equivalent specific gravity values for each orientation differ by more than 0.03 from the combined average, then the average equivalent specific gravity shall be equal to the lowest test value of all bolt diameters and load directions evaluated plus 0.03 for a given orientation. Alternatively, equivalent specific gravity shall be permitted to be determined based on the average of individual equivalent specific gravity values for all bolt diameters in a given combination of orientation and load direction (for example, *Y-X* and *Y-L*, or *X-Y* and *X-L*) provided that they do not differ from the average of all bolt diameters in the combination by more than 0.03. Otherwise, the average equivalent specific gravity shall be equal to the lowest test value of all bolt diameters evaluated in the combination plus 0.03. If dowel bearing tests are conducted in both the *X* and *Y* orientations then an equivalent specific gravity value shall be determined for each orientation. If one equivalent specific gravity is to be specified for both *Y* and *X* orientations then it shall be the lower of the two individual values.

NOTE A2.5—An example calculation is provided in Appendix X3.

A2.7.6 The results from bolt tests can also be applied to lag screws.

A2.7.7 The specified testing establishes the equivalent specific gravity values for the full range of dowel-type (bolts, lag screws, wood screws, and nails) fasteners within the scope of Ref (**4**).

A2.8 Presentation of Connection Properties

A2.8.1 Presentation of connection properties shall state the specific gravity of the equivalent sawn lumber species combination for each fastener type and product orientation evaluated.

A3. TEST PROCEDURE FOR DETERMINING HORIZONTAL SHEAR STRESS IN STRUCTURAL-SIZE MEMBERS OF SCL

A3.1 Scope

A3.1.1 Annex A3 outlines the procedures to be used when determining the allowable shear stress of SCL products based on structural-size member tests. This procedure is based on Test Methods D198 test procedures for short-span edgewise bending and is an alternative to the Test Methods D143 block shear test method. It measures a shear strength value that is considered more representative of shear critical structural end-use applications.

A3.1.2 This procedure applies predominantly to the measurement of shear strength in SCL products in the edgewise (*L-Y* plane or joist) product orientation. Evaluation of SCL horizontal shear strength (**8-10**) has shown that it is difficult to obtain a high percentage of shear failures when conducting short-span, edgewise bending tests on rectangular sections. This test procedure provides an alternate test specimen configuration that has been found to result in a high percentage of shear failures.

A3.1.3 This procedure shall be used to evaluate systematic manufacturing process characteristics that could affect horizontal shear strength that would otherwise be difficult to evaluate in the small Test Methods D143 block shear test.

NOTE A3.1—One example of a systematic manufacturing process characteristic is the use of edge-joined (composed) veneers in the manufacture of LVL. When multiple sheets of composed veneer are used in the manufacture of LVL it is possible to manufacture product that has a number of edge-joined veneers that may be close enough to each other to affect horizontal shear strength. Such production may be difficult to evaluate in the small Test Methods D143 block shear test procedure. Use of the structural-size shear procedure is considered to be a better test method for evaluating the effect of this manufacturing characteristic.

A3.2 Specimen Sampling and Preparation

A3.2.1 Samples for qualification testing shall be representative of the population being evaluated. Sampling of the test material shall be done in accordance with applicable portions of Section 4, Statistical Methodology, of Practice D2915. The minimum sample size shall be 28.

A3.2.2 The test material shall be brought to moisture equilibrium in a conditioned environment of 68 ± 11°F (20 ± 6°C) and 65 % (±5 %) relative humidity. Test material conditioning can be waived when the product moisture content at time of test is within 30 % of the conditioned product moisture content as determined from the comparison of conditioned versus routine quality-control testing requirements of 6.5.1.1.

A3.2.3 *Depth*—The minimum product depth to be evaluated shall be 16 in. (406 mm).

A3.2.4 *Cross-Section*—An *I*-shaped cross-section shall be fabricated by either adding flanges of the same material to the tension and compression zones of the rectangular section or by removing material from the central zone of the rectangular member. The amount of material to be added or removed shall be such that a net web height to the total depth (*h/d*) ratio of 0.5 or greater is maintained and a high percentage of the *I*-shaped test specimens fail in horizontal shear (see Note A3.2).

A3.2.5 *Length*—The test specimen length shall be determined such that it does not extend beyond the ends of the reaction bearing plates.

NOTE A3.2—Figs. A3.1 and A3.2 show example test setups that have shown to provide a high percentage (>90 %) of shear failures. These test specimens were fabricated by joining additional flange material to the rectangular section with an adhesive and nails or wood screws. In these setups, care should be taken to ensure that the glued flanges are flush with or slightly offset inside the edges of the rectangular section material under the load bearing points.

The amount of material to add to or remove from the rectangular cross-section will depend on the relative shear-to-bending strength ratio for a given SCL product. Experience suggests that a total flange width equal to three times the rectangular section width and net web height to total depth (*h/d*) ratio of ½ to ¾ will result in a high percentage of horizontal shear failures. Note that for products with a significant density gradient through its thickness, the removal of material to create an *I*-section may not be appropriate.

A3.3 Test Procedure

A3.3.1 Short-span bending tests shall be conducted in accordance with the principles of Test Methods D198 (see Note A3.3). The test configuration shall be either center-point loading or four-point loading. In the case of four-point loading, the two load heads shall be spaced no more than 6 in. (152.4 mm) apart.

A3.3.2 *Span and Bearing*—The span shall be short enough to provide a high percentage of horizontal shear failures and shall maintain a minimum distance of twice the specimen depth (2d) between the inner edge of the reaction plate and outer edge of the loading plate. The length of the loading plate and the reaction plate supports shall be chosen to minimize product crushing under the plates (see Note A3.3).

NOTE A3.3—A test machine with a 40 000-lb (178-kN) capacity may be required to achieve ultimate loads for a 16-in. (406-mm) deep specimen. To achieve the requirements of A3.3.2 a test span of at least five and one-half times the specimen depth (5½ d) is required. The minimum distance of twice the specimen depth (2d) between the inner edge of the reaction plate and outer edge of the loading plate is recommended to minimize the effect of compressive forces under the loading points on the horizontal shear strength.

A3.3.3 *Speed of Testing*—The test speed shall be chosen to achieve time-to-failures of not less than 5 min.

A3.3.4 *Lateral Supports*—The test specimens shall be laterally supported to prevent lateral instability. Lateral support shall be provided at least at the third-points of the test span and shall allow vertical movement without frictional restraint.

A3.4 Design Stress Determination

A3.4.1 The shear strength for each test specimen shall be calculated using Eq A3.1. The test data may be analyzed based on those data that failed in shear only (uncensored data) and those data containing all failure modes (censored data). For the censored data analysis, the uncensored mean and standard deviation can be estimated by using the methodology for the maximum likelihood estimators (MLEs), as described by Lawless (**11**).

$$\tau_{\text{Apparent}} = \frac{VQ}{It} = \frac{3V}{2t}\frac{\left[bd^2 - (b-t)h^2\right]}{\left[bd^3 - (b-t)h^3\right]} \qquad (A3.1)$$

where:

τ_{Apparent} = calculated shear strength (psi or N/mm^2),
V = ultimate shear force = ultimate load/2 (lbf or N),
Q = first moment (in.^{3} or mm^3),
I = moment of inertia (in.^{4} or mm^4),
t = measured web thickness (in. or mm),
b = measured width of *I*-section (in. or mm),
d = measured depth of *I*-section (in. or mm), and
h = net height of the web between the flanges (in. or mm).

A3.4.2 *Characteristic Value*—The characteristic value shall be determined in accordance with the procedures of 7.2 of this specification.

A3.4.3 *Allowable Design Stress*—The allowable design stress shall be determined in accordance with the procedures of 7.3 and 7.4 of this specification.

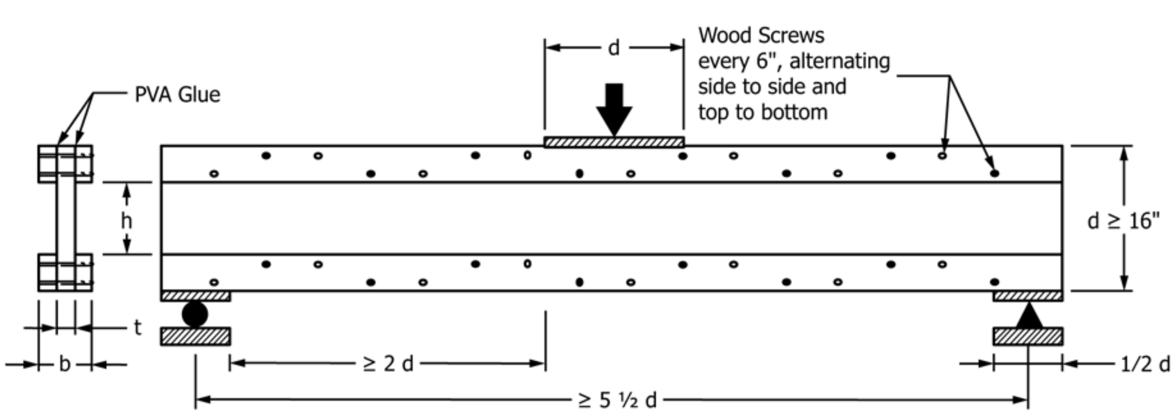
NOTE A3.4—The 16 in. (406 mm) specimen depth is considered to be a deep enough depth such that no adjustment for size effect is required.

A3.5 Report

A3.5.1 The test report shall contain:

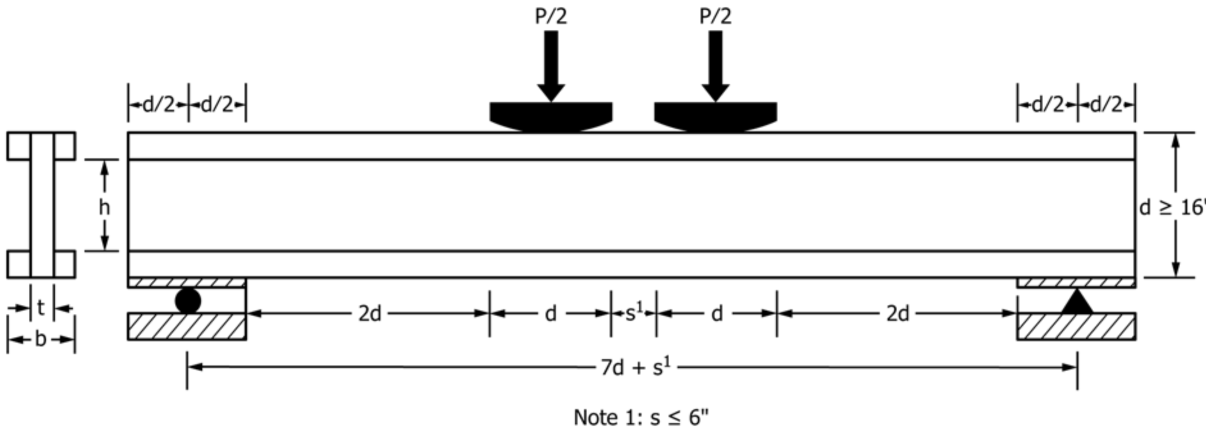
A3.5.1.1 The species and grade under evaluation,

A3.5.1.2 The method of test specimen fabrication,



NOTE 1—1 in. = 25.4 mm.

FIG. A3.1 Example PSL Structural-Size Horizontal Shear Test Set-Up



NOTE 1—1 in. = 25.4 mm.

FIG. A3.2 Example LVL Structural-Size Horizontal Shear Test Set-Up

A3.5.1.3 Description of schematic of the test setup,

A3.5.1.4 The mode of failure including the number of specimens that failed in shear, and

A3.5.1.5 The method of data analysis.

A4. TEST PROCEDURES FOR EVALUATING SCL DURABILITY AND CORE DENSITY

A4.1 Scope

A4.1.1 Annex A4 outlines the procedures for evaluating the adhesive durability, product durability, and connection durability of SCL products based on accelerated aging test methods recognized for other engineered wood products. In addition, Annex A4 provides procedures for evaluating core density of LSL and OSL as a measure of density gradient for these SCL products.

A4.2 Adhesive Durability Tests (Six-Cycle Short Span Bending)

A4.2.1 These optical adhesive durability tests are intended for evaluating the SCL bond durability based on a six-cycle vacuum-pressure-soak procedure adapted from US Product Standard PS 2. Adhesive durability tests shall be conducted in a flatwise short-span bending text for all SCL products. In addition, for LVB, adhesive durability tests shall also be conducted in an edgewise short-span bending test.

A4.2.2 A test population shall be sampled from production that is representative of the product under evaluation. Two matched test groups in pairs shall be selected, one as control, and one for a moisture cycling. A minimum sample size of ten is required for each test group.

NOTE A4.1—Matching specimens for the purposes of A4.2.2, A4.3.2, and A4.4.2 can be side-matched or end-matched.

NOTE A4.2—The difference in the specimen width for LVL and PSL, and LSL and OSL is based on the consideration of predominant thickness for these products. LSL and OSL are typically produced in a smaller thickness than LVL and PSL.

A4.2.2.1 For the flatwise short-span test, the control and moisture-cycled specimens shall have the same dimensions as follows:

(1) For LVL and PSL: thickness by width of 1¾ in. (44.5 mm) by length of (6 × thickness + 1 in. or 25.4 mm)

(2) For LSL and OSL: thickness by width of 1½ in. (38.1 mm) by length of (6 × thickness + 1 in. or 25.4 mm)

(3) For LVB: thickness with a bondline located at the neutral axis by width of 1½ in. (38.1 mm) by length of (6 × thickness + 1 in. or 25.4 mm). See Fig. A4.1.

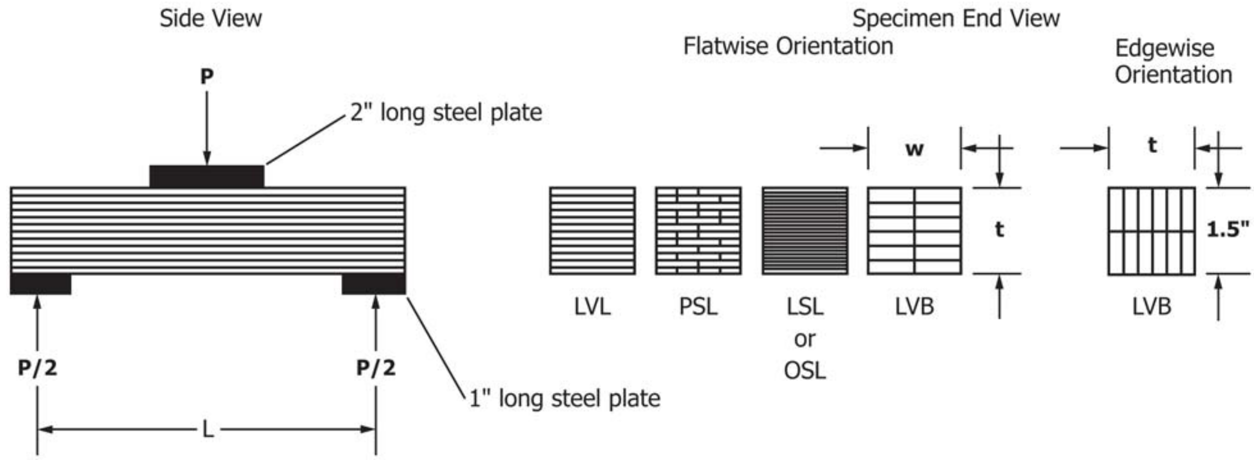
A4.2.2.2 For the edgewise short-span bending test (LVB only), the control and moisture-cycled specimens shall have the same dimensions as follows:

(1) For LVB: 1½ in. (38.1 mm) with a bondline located at the neutral axis by thickness by length of 10 in. (or 254 mm). See Fig. A4.1.

A4.2.3 The moisture-cycled specimens shall be subjected to 6 vacuum-pressure-soak cycles in accordance with Section 7.17 of US Product Standard PS 2. In the final cycle, the moisture-cycled specimens shall be dried to a moisture content that is within ±2 % of the control group.

A4.2.4 Test procedures for adhesive durability shall be in accordance with the requirements specified in this section.

A4.2.4.1 Each specimen shall be simply supported by a 1-in. (25.4-mm) long bearing plate at each end reaction and loaded in the flatwise (plank) or edgewise (joist – LVB only) orientation by a concentrated force through a 2-in. (50.8-mm) long bearing plate at mid-span (that is, center-point bending), as shown in Fig. A4.1.



NOTE 1—1 in. = 25.4 mm.

FIG. A4.1 Setup for Adhesive Durability Tests (Short Span Bending)

A4.2.4.2 The on-center span, L, shall be 6 times the specimen thickness (6t) for the flatwise bending test or 9 in. for the LVB edgewise bending test (see Fig. A4.1). This span-to-depth ratio is selected to promote the interlaminar shear failure. Overhangs beyond end reactions shall not be permitted.

A4.2.4.3 The loading rate shall be such that the 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 applicable procedures of Test Methods D198 or D4761 shall be followed.

A4.2.4.4 Moisture content of each test group shall be measured and recorded immediately after mechanical testing.

A4.2.4.5 The failure load (lbf or N) and mode of failure for each specimen shall be recorded and reported.

A4.2.5 The ratio of the failure load of the moisture-cycled specimen to the failure load of the matched control specimen shall be determined as the strength retention of the paired specimens.

NOTE A4.3—The strength retentions from this product durability test method may provide a useful means to evaluate bond quality for product optimization, quality assurance, or other purposes. The target strength retentions used for evaluation should be based upon similar products that have satisfied relevant durability requirements, control test sets taken prior to an optimization, original qualification materials, or other benchmarks. Further discussion is provided in X2.2.3.

A4.3 Product Durability Tests (Single-Cycle Edgewise Bending)

A4.3.1 The product durability tests are intended for evaluating the SCL durability based on a single vacuum-pressure-soak cycle recognized in US Product Standard PS 2. SCL products evaluated in accordance with this test method satisfy the dry-use conditions specified in 1.4.

A4.3.2 A test population shall be sampled from production that is representative of the product under evaluation. Two matched test groups in pairs shall be selected, one as control, and one for a moisture cycling. A minimum sample size of 10 is required for each test group. The control and moisture-cycled specimens shall have the same dimensions as follows:

(1) For LVL and PSL: thickness by depth of 1¾ in. (45.5 mm) by length of 22 in. (559 mm)

(2) For LSL and OSL: thickness by depth of 1½ in. (38.1 mm) by length of 22 in. (559 mm)

A4.3.3 The moisture-cycled specimens shall be subjected to a one vacuum-pressure-soak cycle in accordance with Section 7.16 of US Product Standard PS 2. The moisture-cycled specimens shall be dried to a moisture content that is within ±2 % of the control group.

A4.3.4 Test procedures for product durability shall be in accordance with the requirements specified in this section.

A4.3.4.1 Each specimen shall be simply supported by a 1-in.- (25.4-mm-) long bearing plate at each end reaction and loaded in the edgewise (joist) orientation by a concentrated force through a 2-in.- (50.8-mm-) long bearing plate at mid-span (that is, center-point bending), as shown in Fig. A4.2.

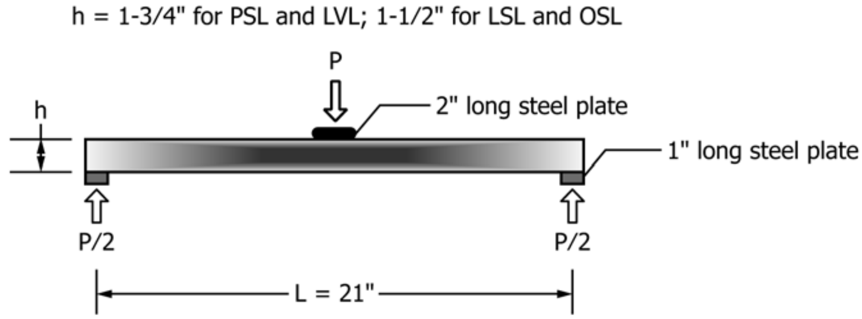
A4.3.4.2 The on-center span shall be 21 in. (533 mm). This span-to-depth ratio is selected to promote the edgewise bending failure.

A4.3.4.3 The loading rate shall be such that the 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 applicable procedures of Test Methods D198 or D4761 shall be followed.

A4.3.4.4 Moisture content of each specimen shall be measured and recorded immediately after mechanical testing.

A4.3.4.5 The failure load (lbf or N) and mode of failure of each specimen shall be recorded and reported.

A4.3.5 The ratio of the failure load of the moisture-cycled specimen to the failure load of the matched control, excluding those specimens that failed in shear, shall be determined as the strength retention of the paired specimens. The average retention, as required in 6.9.1, shall be reported based on the average of strength retention from all specimen pairs.



NOTE 1—1 in. = 25.4 mm.

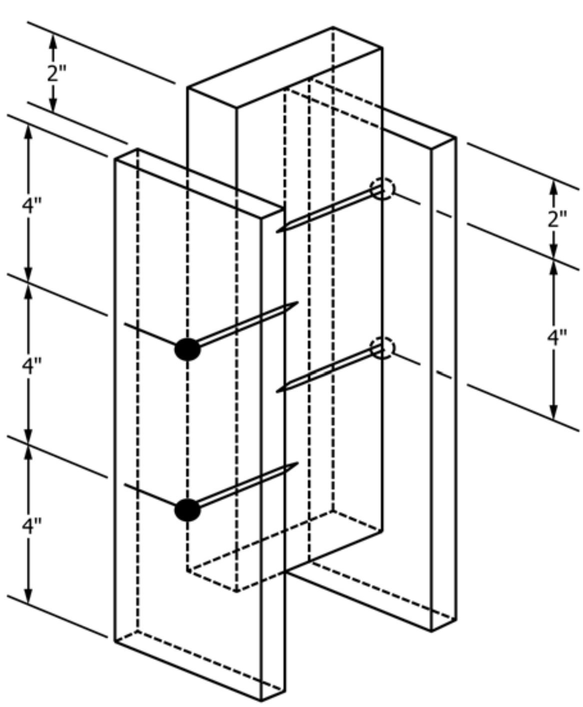
FIG. A4.2 Setup for Product Durability Tests (Edgewise Bending)

A4.4 Lateral Edge Nail Durability Tests (24-h Water Soak Connection Tests)

A4.4.1 The lateral nail durability tests are intended for evaluating the connection durability based on a 24-h water soak specified in Section 6.3.3 of Test Methods D1037. SCL products evaluated in accordance with this test method satisfy the dry-use conditions specified in 1.4.

A4.4.2 A test population shall be sampled from production that is representative of the product under evaluation. Two matched test groups in pairs shall be selected, one as control, and one for a 24-h water soak. A minimum sample size of 10 is required for each test group. The control and water-soaked specimens shall have the same dimensions of 3½ in. (88.9 mm) in width by 12 in. (304.8 mm) in length.

A4.4.3 The control specimens shall be fabricated into the test assembly in accordance with Fig. A4.3. The SCL specimen shall serve as the center of the assembly. The side members of the assembly shall be 23⁄32 in. by 4 in. by 12 in. (18.3 mm × 101.6 mm × 304.8 mm) oriented strand board (OSB). The SCL specimen (main member) is connected to the OSB side members through nailing into the center of the main member edges with 8d (2½ in. or 63.5 mm) bright common nails without coatings. Care shall be taken to ensure that all materials are cut square and the test assembly is fabricated square.



NOTE 1—1 in. = 25.4 mm.

FIG. A4.3 Setup for Lateral Edge Nail Durability Tests (Load-Slip)

NOTE A4.4—It is good practice to develop a test jig to fabricate the assembly.

A4.4.4 The water-soaked specimens shall be subjected to 24-h water soak in accordance with Section 6.3.3 of Test Methods D1037. The specimens shall then be fabricated into the test assembly in accordance with Fig. A4.3 and A4.4.3 while the SCL specimens are still wet (the side members are dry).

A4.4.5 The water-soaked and control groups shall be tested in accordance with A4.4.6 when the average moisture content of the water-soaked group is within ±2 % of the control group.

A4.4.6 Test procedures for lateral edge nail durability shall be in accordance with the requirements specified in this section.

A4.4.6.1 Each assembly shall be tested by compressive loading in accordance with the principles set forth in Section 28 of Test Methods D1761 except that the loading rate shall be 0.1 in./min (2.5 mm/min) and a pre-load of approximately 5 % of the expected ultimate load shall be permitted. The assembly shall be tested to failure or until a deformation, as measured after the pre-load is applied, of 0.4 in. (10.2 mm) is reached. The ultimate load or peak load at 0.4-in. (10.2-mm) deformation shall be recorded and reported.

A4.4.6.2 Moisture content of each SCL test group shall be measured and recorded immediately after mechanical testing.

A4.4.6.3 The failure load (lbf or N) and mode of failure for each specimen shall be recorded and reported.

A4.4.7 The ratio of failure load of the water-soaked specimen to the failure load of the matched control specimen shall be determined as the strength retention of the paired specimens. The average retention, as required in 6.9.2 shall be reported based on the average of strength retention from all specimen pairs.

A4.5 Core Density Tests

A4.5.1 For the purpose of this standard, the core density is defined as the density of the center one-third of the product thickness. This test is intended for LSL and OSL only as a measure of the density gradient in the core of the product. Two test methods can be used to determine the core density. The first method is by means of physical measurements and the second method is by means of a gamma-ray or X-ray densitometer. The oven dry moisture content of the specimens shall be also measured and reported.

A4.5.2 The samples shall be representative of the population being evaluated and tested in the as-received conditions. For qualification testing, specimens shall be taken from the same materials directly adjacent to the materials used for the lateral edge nail durability tests in accordance with A4.4.

A4.5.3 For the core density determination by physical measurements, the specimens shall be prepared by removing ⅓ of the board thickness from each surface, leaving the remaining center ⅓ of the specimen (core) for the density measurement. The specimen size shall be 3½ in. (88.9 mm) in width by 12 in. (304.8 mm) in length. For the core density determination by using a densitometer, the specimens shall be cut to fit the densitometer.

A4.5.4 Test procedures for core density shall be in accordance with the requirements specified in this section.

A4.5.4.1 For the core density determination by physical measurements, the weight of each specimen shall be measured to the nearest 0.1 lb (0.4448 N). The average thickness of the specimen shall be determined by one thickness measurement to the nearest 0.001 in. (0.0254 mm) at each end and one at the mid-point for a total of three measurements. The specimen length and width shall be measured to the nearest 1⁄32 in. (0.8 mm).

A4.5.4.2 For the core density determination by using a densitometer, the instructions of the equipment manufacturer shall be followed to measure the density profile across the thickness of the specimen.

A4.5.5 For the core density determination by physical measurements, the core density shall be calculated using the following formula (Eq A4.1 is for inch-pound units and Eq A4.2 is for SI units):

$$D_c = \frac{1728\,m}{L\,b\,t} \quad (A4.1)$$

where:

D_c = core density (lb/ft^3),
m = mass of the specimen (lb),
L = length of the specimen (in.),
b = width of the specimen (in.), and
t = average thickness of the specimen (in.).

or

$$D_c = \frac{1000\,m}{L\,b\,t} \quad (A4.2)$$

where:

D_c = core density (g/cm^3),
m = mass of the specimen (g),
L = length of the specimen (mm),
b = width of the specimen (mm), and
t = average thickness of the specimen (mm).

A4.5.6 For the core density determination by using a densitometer, the density measurement profile shall be calibrated using a known density object or as in accordance with the instructions of the equipment manufacturer. The core density shall be determined by the average density of the center ⅓ of the specimen from the density profile plot.

A5. EVALUATION OF STRUCTURAL COMPOSITE LUMBER BINDER ADHESIVES

A5.1 Introduction

A5.1.1 This annex was developed to ensure that binder adhesives developed and used in some structural composite lumber (SCL) products, namely laminated strand lumber (LSL) and oriented strand lumber (OSL), are considered suitable for the intended application. This would include the exposure conditions typically associated with SCL products evaluated in accordance with this standard.

The use of this annex beyond binder-type SCL products is the prerogative of the respective product standards. However, it is important to recognize that some binder adhesive performance requirements beyond those specifically detailed in this annex also exist in the main body of the standard, which include heat durability, duration of load/creep performance, thickness swell, internal bond, edgewise bending durability, connection durability tests, and related performance requirements.

A5.2 Scope

A5.2.1 This annex covers procedures for testing and requirements for the evaluation of SCL binder adhesives.

NOTE A5.1—The current adhesives used for some SCL products, such as LSL and OSL, are binder adhesives, which cannot be evaluated in accordance with Specification D2559.

A5.2.2 The SCL binder adhesives are intended for use in SCL products subjected to moisture exposure conditions that are consistent with 1.4.

A5.2.3 Testing and evaluation of non-binder SCL adhesives are beyond the scope of this annex.

A5.3 Significance and Use

A5.3.1 Structural properties of SCL depend on effective and durable adhesive bonds.

A5.3.2 In this annex, performance of SCL binder adhesives for resistance to accelerated aging by two-hour boil, six-cycle vacuum-pressure-soak, and low ambient temperature is evaluated by the retention of interlaminar shear strength. These tests are used in combination with a series of qualification tests that exist in the main body of the standard to demonstrate the suitability of the binder adhesives for use in SCL products.

A5.3.3 Since interlaminar shear strength retention is assessed by short-span bending tests where the induced shear stresses are highest in the middle third of the product thickness, the test methods used in this Annex are intended primarily to evaluate the wood-to-wood bonding (the binder adhesive and wood furnish) conditions in the center third of the product thickness.

NOTE A5.2—The supplemental interlaminar shear test methods used in this Annex were chosen because they impose a realistic stress condition where bond quality is of critical importance. However, their selection is based upon an assumption that a consistent binder system and wood species mixture is used throughout the product thickness. If for example, a different resin were to be used in the shell relative to the core, then these procedures would not necessarily provide a durability review for the shell binder system. In these instances, further evaluation is required. Depending upon the product configuration, it may be possible to run the qualification procedure using trial products produced entirely with the shell or core binder systems, to laminate together multiple plies for the test specimen, or to add joist orientation bending test set or other stress condition that equally stresses both the shell and core layers.

A5.3.4 Requirements for approval and certification of SCL binder adhesives are needed for adhesive manufacturers, SCL manufacturers, test laboratories, qualified agencies, design professionals, and regulatory agencies.

A5.4 Prerequisite Requirements

A5.4.1 *Fillers and Extenders*—If amylaceous or protein fillers and extenders are used, the adhesive must meet the requirements of this standard and possess sufficient anti-fungal properties to inhibit the growth of selected fungal species when tested in accordance with Test Methods D4300. The adhesive manufacturers shall state in their bulletin whether such materials are present.

A5.4.2 *Chemical Requirements*—The cured adhesive film shall develop a pH value of not less than 2.5 when tested in accordance with Test Method D1583.

A5.4.3 *Additives*—If additives, such as catalysts, hardeners, accelerators, modifiers, or inhibitors, or combinations thereof, are used, the adhesive in combination with the additive must meet the requirements of this annex.

A5.4.4 *Bacteria Resistance*—SCL products with binder adhesives shall be tested in accordance with 7.15 of PS 2 and meet the requirements specified in 6.2.5.3 of PS 2. Phenolic and isocyanate-based binder adhesives have demonstrated resistance to attack from bacteria and shall be considered as meeting this requirement.

A5.5 Qualification Test Requirements

A5.5.1 Qualification tests shall be conducted on interlaminar shear specimens under accelerated aging with 2-hour boil and 6-cycle vacuum-pressure-soak (VPS), and low ambient temperature (0°F or -18°C), as specified in A5.6 – A5.10. The retention of SCL properties after accelerated aging treatments is used as the qualification criteria for these tests, as specified in A5.11.

A5.6 Sampling

A5.6.1 A test population shall be sampled from production that is representative of the SCL product manufactured with the binder adhesive under evaluation. When modification to the process results in a reduction to the bond quality, as indicated by the quality assurance results, a new adhesive qualification is required.

A5.6.2 The predominant species mix with representative specific gravity shall be used for testing and evaluation. The SCL manufacturer and the qualified agency shall determine the acceptable species mix for qualification.

A5.6.3 The product thickness and grade chosen for testing shall be that which employs the lowest adhesive content. The specimen thickness shall not be less than the minimum anticipated structural size at the time of qualification.

A5.6.4 Minimum sample sizes shall be in accordance with Table A5.1.

TABLE A5.1 Minimum Sample Size—Interlaminar Shear Tests

Test Group	Minimum Sample Size
Control	20
2-Hour Boil	20
6-Cycle vacuum-pressure-soak (VPS)	20
Low Ambient Temperatures (-0°F or -18°C)	20

A5.6.5 Matched groups shall be selected for the test groups of Table A5.1. Any edge or end coatings, sealers, or treatments shall be removed from all specimens.

NOTE A5.3—Matching specimens can be end-matched or side-matched. Fig. A5.1 shows an example of an acceptable cutting pattern for specimen matching.

A5.7 Pre-Conditioning and Specimen Measurement

A5.7.1 SCL used in the adhesive durability testing shall be brought to moisture equilibrium under indoor ambient conditions prior to the individual specimen preparation. Methods for determination of conditioning are provided in Guide D4933.

A5.7.2 After cutting into individual test specimens for each test group, all specimens shall be kept in the same indoor ambient environment until the specific test is conducted.

A5.7.3 The dimensions and weight of each specimen shall be recorded before any accelerated aging cycle or low temperature exposure.

A5.7.4 Moisture content and specific gravity shall be reported for specimens tested in the qualification, unless noted otherwise in the specific test procedures. Measurement of moisture content shall be in accordance with Methods D4442 and measurement of specific gravity shall be in accordance with Methods D2395. As an alternative to specific gravity, it shall be permitted to report density at the reported moisture content.

A5.8 Accelerated Aging Cycles and Low Temperature Exposure

A5.8.1 *Two-hour boil*—the two-hour boil aging tests shall be conducted as follows:

A5.8.1.1 Submerge the specimens to be aged in boiling water for at least 2 h.

A5.8.1.2 After the 2-h boil, immediately submerge the specimens for not less than 1 h in water with an initial temperature less than 77°F (25°C).

A5.8.1.3 Dry the specimens to a moisture content that is within ±2 % of the original weight in an oven with a temperature of not less than 180°F (82°C).

A5.8.1.4 Cool the specimens to room temperature prior to mechanical testing.

A5.8.2 *Six-cycle vacuum-pressure-soak (VPS)*—The VPS aging tests shall be conducted as follows:

A5.8.2.1 Subject the specimens to 6 VPS cycles in accordance with Section 7.17 of PS 2.

A5.8.2.2 Following the last cycle, dry the specimens to a moisture content that is within ±2 % of the original weight in an oven with a temperature of not less than 180°F (82°C).

A5.8.2.3 Cool the specimens to room temperature prior to mechanical testing.

A5.8.3 *Low ambient temperatures*—The low ambient temperature exposures shall be conducted as follows:

A5.8.3.1 Place the specimens in a chamber with a temperature less than 0°F (-18°C) for a period of not less than 24 h.

A5.8.3.2 Remove one specimen at a time from the chamber and perform the shear test within 1 min.

A5.9 Interlaminar Shear (Short-Span Flatwise Bending) Testing

A5.9.1 Interlaminar shear tests shall be conducted in accordance with A4.2 using control, accelerated aging, and low temperature specimens in accordance with A5.6.

A5.10 Calculations

A5.10.1 The peak shear strength for each interlaminar shear test shall be calculated and reported based on the specimen dimensions prior to any aging or low temperature exposure.

A5.10.2 The peak shear strength for each interlaminar shear test specimen shall be calculated and reported in accordance with Eq A5.1.

$$f_v = \frac{3\ P_u}{4A} \tag{A5.1}$$

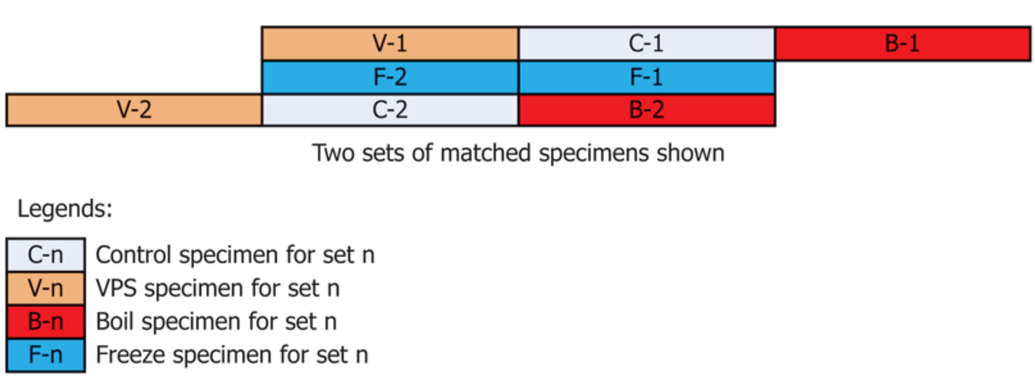


FIG. A5.1 An Example for Matched Specimens

Where:

f_v = Peak interlaminar shear strength, psi (N/mm^2)
P_u = Peak total load measured in the interlaminar shear test, lbf (N), and
A = Specimen cross-sectional area based on the specimen dimensions prior to any aging or low temperature exposure, in.^{2} (mm^2).

A5.10.3 The average and coefficient of variation of the peak shear strength for accelerated aging and low temperature exposure test sets (2-h boil, 6-cycle VPS, and low temperature exposure), and the matched control test set shall be calculated and reported.

A5.10.4 The strength retention ratio for each test set shall be calculated and reported by dividing the average peak shear strength for each accelerated aging and low temperature exposure test set by the average peak shear strength for the matched control test set, as shown in Eq A5.2.

$$R_i = \frac{f_{v,\,i}}{f_{v,\,control}} \quad (A5.2)$$

Where:

R_i = Strength retention ratio for each interlaminar shear test set i, where i = 2-h boil, 6-cycle VPS, or low temperature exposure,
$f_{v,i}$ = Average interlaminar shear strength for shear test set i, psi (N/mm^2), and
$f_{v,\,control}$ = Average interlaminar shear strength for matched control test set, psi (N/mm^2).

A5.11 Interlaminar Shear Performance Requirements

A5.11.1 The targeted retention ratio for each interlaminar shear test set is shown in Table A5.2.

TABLE A5.2 Property Retention Targets—Interlaminar Shear

Test Set, I	Targeted Strength Retention Ratio for Interlaminar Shear, $R_{targeted,\,I}$
2–Hour Boil	0.65
6–Cycle VPS	0.60
Low Ambient Temperatures (-0°F or -18°C)	1.00

A5.11.2 The required strength retention ratio for each interlaminar shear test set shall be determined and reported in accordance with Eq A5.3.

$$R_{required,\,i} = R_{targeted,\,i}\left(1 - \frac{t\,V}{\sqrt{N}}\right) \quad (A5.3)$$

Where:

$R_{required,i}$ = Characteristic strength retention ratio for interlaminar shear test set i, where i=2–h boil, 6–cycle VPS, or low temperature exposure, or low temperature exposure,
$R_{targeted,i}$ = Targeted strength retention ratio for interlaminar shear test set i, as specified in Table A5.2,
t = Student t statistic with 95 % confidence developed using the sample size of the related control test set (see Table 1 of Practice D2915); t=2.093 for N=20 specimens (19 degrees of freedom),
V = Coefficient of variation for the related control test set; $V \leq 0.2$ (when V is greater than 0.2, use 0.2 in the calculation), and
N = Sample size for the related control test set.

A5.11.3 The strength retention ratio for each interlaminar shear test set (R_i), as calculated in accordance with A5.10.4 shall not be less than the required strength retention ratio for the respective accelerated aging or low temperature exposure test set ($R_{required,i}$), as determined in accordance with A5.11.

A5.12 Report

A5.12.1 In addition to each of the test measurements and calculated quantities required above, the report shall include the following:

A5.12.1.1 Identification of the adhesive tested.

A5.12.1.2 Identification of the type of SCL fabricated for testing (that is, LSL, OSL, etc.).

A5.12.1.3 Bonding conditions used in manufacturing the test materials.

APPENDIXES

(Nonmandatory Information)

X1. PRODUCT EVALUATION CRITERIA FOR CODE COMPLIANCE

NOTE X1.1—This appendix is included in this specification as nonmandatory information, but is written in mandatory language to facilitate adoption by regulatory agencies and product certification bodies.

X1.1 Introduction

X1.1.1 The purpose of these criteria is to establish certification requirements for structural composite lumber (SCL) products, as defined in this specification, in accordance with national or local building codes.

NOTE X1.2—Examples of national building codes are International Building Code (IBC, (**12**)), International Residential Code (IRC, (**13**)), and the National Building Code of Canada (NBCC, (**14**)). The IBC and IRC have since their inception in 2000 recognized SCL as a group of approved construction materials. The recognition of SCL under the NBCC is through applicable clauses of CSA O86 Engineering Design in Wood (**15**) and other NBCC provisions.

X1.2 Scope

X1.2.1 Structural composite lumber products covered by these criteria are limited to solid rectangular members. Structural composite lumber products used as rim boards, I-joist flanges, truss chords, load bearing studs, and in shearwall and fire-resistance-rated assemblies require additional evaluation.

NOTE X1.3—Specification D7672 (**16**) and ANSI/APA PRR 410 (**17**) provide procedures for evaluating SCL rim boards. Specification D5055 provides guidance for SCL used as I-joist flanges. Practice E119 and Practice D6513 (**18**) provide guidance for the evaluation of SCL in fire-resistance rated assemblies. In addition, code evaluation agencies may provide acceptance or evaluation criteria for applications not covered by this appendix. For example, ICC-ES AC124 (**19**) provides guidance for the evaluation of SCL rim boards and ICC-ES AC202 (**20**) provides guidance for the evaluation of SCL as load bearing studs in shearwall assemblies and SCL in fire-resistance rated assemblies. Other acceptance or evaluation criteria established by code evaluation agencies are not precluded from consideration.

X1.3 Definition

X1.3.1 Structural composite lumber products covered by these criteria are defined in Section 3. Additional definitions that are specific to these acceptance criteria are included as follows:

X1.3.2 *manufacturer*—a firm or corporation producing a product that complies with this specification.

NOTE X1.4—A manufacturer is considered to be an organization as defined in ISO 9000:2005 (**21**).

X1.3.3 *manufacturer plant technical director (MPTD)*—a quality professional employed by the manufacturer who has demonstrated competence in implementing a quality management system at the plant level.

X1.3.4 *manufacturer technical expert (MTE)*—a quality professional employed by the manufacturer who provides specific knowledge of or expertise on products covered under these acceptance criteria and has demonstrated competence in managing and implementing a quality management system.

X1.3.5 *monthly quality report*—a monthly quality report that contains a summary of product performance by grade or series with a comparison to requirements and a discussion of significant changes in raw materials and process.

X1.3.6 *qualified certification agency*—an agency meeting the following requirements:

(a) has trained personnel to perform product certification in compliance with all applicable requirements specified in this standard,

(b) has procedures to be followed by its personnel in performance of the certification,

(c) has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being certified,

(d) is not owned, operated, or controlled by any such company, and

(e) is accredited as complying with ISO/IEC 17065 by a recognized[7] accreditation body for the certification of SCL.

X1.3.7 *qualified inspection agency*—an agency meeting the following requirements:

(a) has trained personnel to verify that the grading, measuring, species, construction, bonding, workmanship, and other characteristics of the products as determined by inspection are in compliance with all applicable requirements specified in this standard,

(b) has procedures to be followed by its personnel in performance of the inspection,

(c) has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being inspected,

(d) is not owned, operated, or controlled by any such company, and

(e) is accredited as complying with ISO/IEC 17020 by a recognized[7] accreditation body for the inspection of SCL.

X1.3.8 *qualified testing agency*—an agency meeting the following requirements:

(a) has access to the facilities and trained technical personnel to conduct testing on the characteristics of the products by sampling and testing in compliance with all applicable requirements specified in this standard,

(b) has procedures to be followed by its personnel in performance of the testing,

(c) has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being tested,

(d) is not owned, operated, or controlled by any such company, and

(e) is accredited as complying with ISO/IEC 17025 by a recognized[7] accreditation body for the tests required by this specification.

NOTE X1.5—The qualified certification agency, qualified inspection agency, and qualified testing agency may be the same agency.

X1.3.9 *quality manual*—a document that establishes the minimum requirements for manufacturing practices, staff, facilities, equipment, and specific quality assurance processes, including inspection (in the U.S.) and/or certification (in Canada), by which the product is manufactured.

NOTE X1.6—The initial quality manual and all revisions shall be signed and dated by the third-party technical expert (TPTE) and manufacturer technical expert (MTE).

X1.3.10 *third-party auditor (TPA)*—a quality professional employed by the accredited inspection agency who has demonstrated competence in auditing a quality management system at the plant level.

X1.3.11 *third-party technical expert (TPTE)*—a quality professional employed by the accredited inspection agency who provides specific knowledge of or expertise on products covered under these acceptance criteria and has demonstrated competence in managing a quality audit system.

X1.4 Test and Analysis

X1.4.1 *General*—Sampling, conditioning, testing, and analysis of data shall be in accordance with this specification.

X1.4.2 *Specimen Sampling*—Sampling shall be performed by a qualified inspection, testing or certification agency, as defined in these criteria, or by the manufacturer under the supervision of a qualified inspection, testing, or certification agency. Sampling methods shall comply with 6.2. The qualified agency supervising the sampling shall confirm that the samples

[7] Recognized by the authority having jurisdiction (AHJ) or an agency verifying code compliance for the AHJ.

are representative of the production in accordance with the requirements of the in-plant quality control manual.

X1.4.3 *Specimen Description*—Specimens shall be described in detail, including at a minimum, the SCL type and grade; wood species; veneer, strand, or lamination dimensions; veneer or lamination grade(s); adhesives; and the manufacturing date and facility.

X1.4.4 *Testing Laboratories*—Testing shall be conducted by a qualified testing agency acceptable to the qualified certification agency. Testing shall be also permitted to be conducted at the manufacturer's testing facility, accredited or not, under the supervision of a qualified testing agency or certification agency. The manufacturer's testing facility is considered a subcontractor of the qualified testing agency or certification agency, and qualification tests conducted at a manufacturer's facility shall be under the control of, witnessed by, and approved by the qualified testing agency or certification agency as conforming to this specification.

X1.4.5 *Test Reports*—Test reports shall be issued or approved by the qualified testing agency or certification agency, and be limited to the products as tested.

NOTE X1.7—Practice E575 (**22**) provides guidance that may be considered for preparing reports from test data.

X1.5 Quality Control

X1.5.1 Quality control shall comply with Sections 8 – 10 at each manufacturing facility. The products shall be manufactured under a quality control program with inspections by a qualified inspection agency acceptable to the qualified certification agency. The inspection frequency shall be established by the qualified certification agency based on the quality level of the manufacturer, as specified in this section.

X1.5.2 Quality assurance levels for a manufacturer shall be established using a documented quality management system. Level l requirements noted in Table X1.1 are set to coincide with the historical engineered wood industry practices.

X1.5.3 Quality system documentation complying with Sections 9 and 10 shall be submitted to and approved by the qualified certification agency for each facility manufacturing or labeling products that are recognized under these criteria.

X1.5.4 *Quality Management System Requirements:*

X1.5.4.1 The manufacturer shall establish and implement a quality management system that is fully documented in accordance with the requirements of Table X1.1. The documented quality management system shall describe the manufacture's procedures and quality activities for ensuring that the products meet the specified requirements.

X1.5.4.2 The manufacturer, in concert with the qualified inspection agency, shall prepare and submit to the qualified certification agency its documented quality manual, including a cross-reference matrix to the quality management system.

X1.5.4.3 The MPTD shall submit a monthly quality report to the TPTE and MTE.

X1.5.4.4 The submitted quality management system shall be assigned a Level l, ll, Ill, or IV.

X1.5.4.5 For Levels II, Ill, and IV, the TPA shall verify conformity to the quality plan at each audit. For Levels III and IV, a senior-level TPA appointed by the TPTE shall audit the plant together with the TPA once each year.

X1.5.4.6 *Follow-up Inspections*—The manufacturer shall obtain the services of a qualified inspection agency to conduct inspections of the fabrication facility in accordance with the minimum inspection frequency specified in Table X1.1.

X1.5.5 *Audit by Qualified Certification Agency*—Prior to advancement to Level IV, the manufacturer is required to undergo an on-site assessment by the qualified certification agency. This audit will be conducted jointly with the qualified inspection agency. The purpose of this joint audit is to determine the manufacturer's compliance with the documented quality management system, and to assess the inspection procedures of the inspection agency. After the audit frequency has been established by the qualified certification agency, any reductions in audit frequency by the third party (i.e., promotion from 3 to 2 audits/year) shall require an additional joint audit and appropriate documentation that the third-party certification or inspection agency has reviewed and approved the revised quality management system. Documentation shall be retained on file by the qualified certification or inspection agency. The qualified certification agency shall approve any ISO and qualified inspection agency combination inspections.

X1.5.6 Prior to advancement to Levels II or Ill, the manufacturer is required to undergo an assessment by the TPTE. The purpose of the assessment is to determine if the manufacturer's quality system meets the minimum requirements of the proposed quality assurance level in Table X1.1. Documentation of the assessment shall be retained on file by the qualified certification or inspection agency.

X1.5.7 *Manufacturer Technical Expert (MTE) Responsibilities*—The manufacturer shall appoint an MTE that reports directly to the highest level of authority within the business or operating unit of the organization. The MTE shall be capable of providing leadership within the quality organization in the following areas:

(a) Development of organizational structure.

(b) Formulation of quality policies and procedures.

(c) Establishment of quality performance goals.

(d) Implementation of quality control tools and process control limits.

(e) Statistical analysis and qualitative assessment of process and product performance.

(f) Supplier assessment, certification, feedback and improvement

(g) Follow-up on customer feedback or field complaints.

(h) Establish training and development programs for MPTD and other associates.

(i) Maintain the manufacturer's documented quality system.

(j) Monitor the effective implementation of the manufacturer's documented quality system.

(k) Assure that periodic internal audits are conducted and documented, and that corrective actions are implemented.

(l) Assure that annual management reviews are conducted and documented to assure the adequacy and effectiveness of

TABLE X1.1 Quality Assurance Levels I, II, III or IV Manufacturers

Quality Concept	Level I Manufacturer	Level II Manufacturer	Level III Manufacturer	Level IV Manufacturer
	Product Audit through Industry Standards	Product Audit through Industry Standards	ISO Compliant – Ready to Register[G]	ISO Registered[C]
Minimum Audit Frequency by TPA	12 / year	6 / year	4 / year	3,2 / year[D]
MTE and MPTD Education and Experience	Industry Experience	X1.5.9.7 and X1.5.9.8	X1.5.9.7 and X1.5.9.8	X1.5.9.7 and X1.5.9.8
Intra-Company Quality Audits at Every Plant by MTE[A, B, H]	N/A	N/A	1 /year	1 / year
Plant Quality Audit by MPTD[F, H]	N/A	1 / year	1 / year	2 / year
Review of QA Test Results[I]	1 / year (MTE) Monthly (MPTD)	1 / year (MTE) Monthly (MPTD)	2 / year (MTE) Monthly (MPTD)	2 / year (MTE) Monthly (MPTD)
Quality Manual	Yes	Yes	Yes	Yes
Documentation in accordance with ISO 9001-2000 **(23)**	No	No	Yes	Yes
Quality Plan[E]	No	Yes	Included in ISO Documentation	Included in ISO Documentation
Monthly QC report by MPTD required	Yes	Yes	Yes	Yes

[A] Intra-company auditors can be from different plants. For companies with multiple plants, the MTE may designate a lead auditor that satisfies the education and experience requirements of an MTE. The MTE, however, still retains the primary responsibility for the quality management system.
[B] External auditors shall be permitted to be contracted in cases where a company has only one plant.
[C] To move from Level III to Level IV, successful documentation under these acceptance criteria for a minimum of two years is required in addition to ISO 9001 certification. Additionally, an on-site joint audit with third-party auditor and the qualified certification agency participation is required. Registration shall be conducted by an ISO 9001 agency registered by a registrar accredited by an International Accreditation Forum (IAF) member accreditor or an ISO 9000 registrar accredited by an IAF member accreditor.
[D] Successful documentation and ISO registration for a minimum of two years are required for a move from three audits to two audits per year by the qualified inspection agency. Additionally, an on-site joint audit with third-party auditor and the qualified certification agency participation is required.
[E] A quality plan provides information beyond the quality manual and shall be verified in accordance with X1.5.4.5. It shall include revision-controlled documents, retrievable records and procedures defining the following:
(a) Product identification and traceability from raw materials to finished goods.
(b) Corrective and preventative action process that can track/trend incidents of nonconforming product from identification through root cause analysis to resolution and closure.
(c) Internal audit process to ensure that the procedures are being followed.
[F] The MPTD shall audit each element of the quality plan (Level II) or quality management system (Levels III and IV).
[G] Requires review of documentation by the qualified inspection agency and the manufacturer.
[H] The intra-company quality audit by MTE and plant quality audit by the MPTD are conducted separately.
[I] The MTE shall review QA test results in accordance with 10.6. See X1.3.4 and X1.5.4.3 for MPTD requirements.

the quality system. Management reviews shall include a summary and a documented plan of action for improvement.

(m) Be familiar with and demonstrate knowledge of codes and standards as applicable to the quality assurance program.

(n) Be an employee of the manufacturer who reports quality information and decisions directly to the highest level of authority within the business or operating unit of the organization.

X1.5.8 *Manufacturer Plant Technical Director (MPTD) Responsibilities*—The manufacturer shall appoint an MPTD at each production facility who shall:

(a) Understand the organizational structure.

(b) Implement the quality policies and procedures at the plant level.

(c) Monitor and report the plant quality performance to the MTE.

(d) Apply quality control tools and process control limits at the plant level.

(e) Collect and report information to provide a qualitative assessment of process and product performance.

(f) Collect information for supplier assessment, certification, feedback and improvement.

(g) Investigate customer feedback or field complaints.

(h) Participate in training and development programs.

(i) Maintain the manufacturers documented quality system at the plant level.

(j) Be responsible for overall workmanship and for compliance to the documented procedures established by the manufacturer. Although inspections may be delegated to qualified personnel during the receipt and in-process stages of assembly, it is the responsibility of the MPTD to ensure that inspections are performed.

(k) Be responsible for ensuring that incoming raw materials are properly identified and inspected for compliance with quality plans and specifications.

(l) Be responsible for ensuring that the final QC test results can be traced back to the incoming raw materials, the quality assurance records and the responsible plant personnel.

(m) Train and monitor performance of other personnel collecting process or product performance data.

(n) Be an employee of the manufacturer that reports quality information directly to the MTE.

X1.5.9 *Education and Experience:*

X1.5.9.1 *Education and Experience for MTE, MPTD, TPTE or TPA*—MTE and MPID shall be identified in the quality manual on the basis of appropriate education, training and experience such that the individuals are competent to take full charge of their responsibilities in accordance with the requirements noted in this section and also as required by the qualified inspection agency.

X1.5.9.2 Educational and experience requirements for qualified inspection agency personnel shall be in accordance with Table X1.2.

X1.5.9.3 The TPTE shall verify the education and experience, proof of professionalism and core knowledge of the MTE.

X1.5.9.4 The MTE shall verify the education and experience, proof of professionalism and core knowledge of the MPTD.

X1.5.9.5 *Experience Waiver for Education*—If an individual has completed a degree from an accredited college, university or technical school, or certification by the American Society for Quality (ASQ), part of the experience requirement shall be permitted to be waived as follows:

(a) Diploma from technical or trade school or advanced degree from non-related field – one year waived.

(b) Associate degree in Forest & Wood Sciences, Engineering, or a related field – two years waived.

(c) ASQ Certified Quality Improvement Associate, Quality Engineer, Reliability Engineer, Six Sigma Black Belt, or Quality Technician – two years waived.

(d) ASQ Certified Quality Auditor – three years waived.

(e) Bachelor's degree in Forest & Wood Sciences, Engineering, or a related field – four years waived.

(f) Master's or Doctorate degree in Forest & Wood Sciences, Engineering, or a related field – five years waived.

(g) ASQ Certified Quality Manager – five years waived.

(h) Professional Engineer registration – ten years waived.

X1.5.9.6 *Proof of Professionalism*—The MTE, MPTD, TPTE and TPA shall demonstrate proof of professionalism in one of three ways:

(a) Membership in ASQ, American Society of Civil Engineers (ASCE), or one other trade association applicable to the product produced.

(b) Registration as a professional engineer.

(c) The signatures of two persons, either an accredited inspection agency, ASQ, or trade association member that can verify that the individual is a qualified practitioner of the quality sciences.

X1.5.9.7 *Manufacturer Technical Expert (MTE)*—The MTE shall meet the following minimum requirements:

(a) Ten years of on-the-job experience in one or more areas of X1.5.7 or X1.5.8 (see also X1.5.9.5). A minimum of five years of this experience shall be in a decision-making position. *Decision-making* is defined as the authority to define, execute or control projects/ processes and to be responsible for the outcome. This may or may not include management or supervisory positions. Current or previous certification by the ASQ as a Quality Auditor, Reliability Engineer, Software Quality Engineer, or Quality Engineer applies to job experience. On-the-job experience may be earned in accordance with the education requirements in X1.5.9.5.

(b) The MTE shall demonstrate an adequate knowledge of core subjects by satisfying education requirements of X1.5.9.5(e) and X1.5.9.5(f), or a minimum of 25 continuing education unit (CEU) or recertification unit (RU) credits (or equivalent hours of college education) from the list of topics in X1.5.9.7(d) or X1.5.9.10. At least 15 CEU or RU credits shall come from the core knowledge topics in X1.5.9.11. A one-year grace period, beginning on the date of the job appointment, is permitted to acquire the appropriate number of credits while working in the MTE position.

TABLE X1.2 Educational and Experience Requirements for Qualified Inspection Agency Personnel

Quality Level[A]	Level I	Level II	Level III	Level IV
Third-Party Accreditation	Qualified Inspection Agency	Qualified Inspection Agency	Qualified Inspection Agency	Qualified Inspection Agency[B]
TPTE Education and Experience	Industry Experience	X1.5.9.9	X1.5.9.9	X1.5.9.9
TPA Education and Experience	Industry Experience	X1.5.9.10	X1.5.9.10	X1.5.9.10
Third-Party Witness of Manufacturer's Manufacturing / Testing with TPA	Industry Experience, Able to Verify Compliance to Appropriate ASTM Standards	Same as Level I	Same as Level I	Same as Level I

[A] See Table X1.1 for quality system elements.
[B] The organization that ISO registers the manufacturer (i.e., separate organization) shall be either: *(a)* ISO 9001 registered by a registrar accredited by an IAF member accreditor, or *(b)* ISO 9000 registrar accredited by an IAF member accreditor.

(c) The MTE shall demonstrate ongoing training by completing at least 4.5 RU credits every three years in accordance with X1.5.9.7(d).

NOTE X1.8—4.5 credits or 45 h is equivalent to 15 h/year, which is considered as a typical benchmark for a professional engineer.

(d) One RU credit is equivalent to one CEU credit or ten hours of participation. Recertification units can be earned in the following areas:

(1) Author or co-author of a published book or journal article.

(2) Reviewer of a published article or book.

(3) Participation in standards committees such as ASTM, ANSI, etc.

(4) Participation in trade association technical committees or conference presentations.

(5) Participation in the qualified certification agency approved technical meetings.

(6) Being an instructor or student within the topics of X1.5.9.10.

X1.5.9.8 *Manufacturer Plant Technical Director (MPTD)*—The MPTD shall meet the following minimum requirements:

(a) Two years of on-the-job experience in one or more areas in X1.5.8 (see also X1.5.9.5). On-the-job experience may be earned in accordance with the education requirements in X1.5.9.5.

(b) The MPTD shall demonstrate an adequate knowledge of core subjects by satisfying education requirements of X1.5.9.5(b), X1.5.9.5(e), X1.5.9.5(f), or a minimum of 10 CEU or RU credits (or equivalent hours of college education) from the list of topics in X1.5.9.7(d) or X1.5.9.10. At least 5 CEU or RU credits shall come from the core knowledge topics in X1.5.9.11. One year of experience beyond the minimum of three years may be substituted for one CEU or RU. A maximum of 5 credits may be obtained through additional experience served under the guidance of a MTE. A one year grace period, beginning on the date of the job appointment, is permitted to acquire the appropriate number of credits while working in the MPTD position.

X1.5.9.9 *Third-Party Technical Expert (TPTE)*—The TPTE shall meet the following minimum requirements:

(a) Ten years of on-the-job experience in one or more areas related to quality assurance in the wood products industry (see X1.5.9.5). A minimum of five years of this experience shall be in a decision making position. "Decision-making" is defined as the authority to define, execute or control projects/ processes and to be responsible for the outcome. This may or may not include management or supervisory positions. Current or previous certification by ASQ as a Quality Auditor, Reliability Engineer, Software Quality Engineer, or Quality Engineer applies to job experience. On-the-job experience may be earned in accordance with the education requirements in X1.5.9.5.

(b) The TPTE shall demonstrate an adequate knowledge of core subjects by satisfying education requirements of X1.5.9.5(e), X1.5.9.5(f), or a minimum of 25 CEU or RU credits (or equivalent hours of college education) from the list of topics in X1.5.9.7(d) or X1.5.9.10. At least 15 CEU or RU credits shall come from the core knowledge topics in X1.5.9.11. A one year grace period, beginning on the date of the job appointment, is permitted to acquire the appropriate number of credits while working in the TPTE position.

(c) The TPTE shall demonstrate ongoing training by completing at least 4.5 recertification units (RU) every three years in accordance with X1.5.9.7(d).

NOTE X1.9—4.5 credits or 45 h is equivalent to 15 h/year, which was considered as a typical benchmark for a professional engineer.

X1.5.9.10 *Third-Party Auditor (TPA)*—The TPA shall meet the following minimum requirements:

(a) Three years of on-the-job experience in one or more areas related to quality assurance in the wood products industry (see X1.5.9.5). On-the-job experience may be earned in accordance with the education requirements in X1.5.9.5.

(b) The TPA shall demonstrate an adequate knowledge of core subjects by satisfying education requirements of X1.5.9.5(b), X1.5.9.5(e), X1.5.9.5(f), or a minimum of 12 CEU or RU credits (or equivalent hours of college education) from the list of topics in X1.5.9.7(d) or X1.5.9.10. At least 6 CEU or RU credits shall come from the core knowledge topics in X1.5.9.11. One year of experience beyond the minimum of three years may be substituted for one CEU or RU. A maximum of 6 credits may be obtained through additional experience served under the supervision of a TPTE. A one-year grace period, beginning on the date of the job appointment, is permitted to acquire the appropriate number of credits while working in the TPA position.

X1.5.9.11 *Continuing Education Credits:*

(1) The definition of one CEU credit is ten contact hours of participation in an organized continuing education / training experience under responsible, qualified direction and instruction. A contact hour is defined as a 60-minute clock hour of interaction between student and instructor.

(2) If CEU credits are not offered for a given course, then recertification (RU) credits can be calculated. The instructor shall record the hours of interaction between the student and instructor and assign one RU credit for every ten hours of participation in training.

(3) All ASQ certified courses are deemed acceptable for CEU credits. Courses, conferences and seminars offered within the industry are deemed acceptable, provided CEU credits are offered. The following list of topics is considered to be the core knowledge of the overall training program:

(a) ICC Codes, Approvals, Evaluation and Building Official Acceptance.

(b) Role of the Third-Party Agency and Internal Auditing.

(c) North American Wood Design.

(d) Structural versus Serviceability Requirements.

(e) ASTM or ANSI Product Standards.

(f) Grading Procedures for Base Materials.

(g) ASTM or ANSI Testing Procedures, Failure Modes.

(h) Third-Party Witnessing and Report Requirements.

(i) Statistical Method Used to Assign Design Properties.

(j) Fastener Testing / Design.

(k) Preservative Treatment Effects on Product (if applicable).

(l) Durability and Adhesive Test Requirements.

(m) Product Labeling and Traceability to Process.

(n) Business Corporate Quality Structure, Policies and Procedures.

(o) Business Quality Goals.

(p) Continuous Improvement and Innovation.

(q) Assessing Capability of Production Personnel.

(r) Procedures for Nonconforming Product or Base Materials.

(s) Application of ISO 9000 Standards to Quality Process.

(t) Auditing Procedures.

(u) Internal Auditing Procedures.

(v) ISO/IEC 17065, 17025, or 17020 requirements

(w) Document Control and Record Keeping within the Organization.

(x) Fire Testing / Performance.

(y) Other topics as approved by Qualified Certification or Inspection Agency.

X1.6 Product Certification

X1.6.1 The product certification shall be issued by a qualified certification agency.

X1.6.2 The certified product shall be clearly and properly identified by product name, company name or logo, plant location or number, qualified inspection agency name or logo, qualified certification agency name or logo, and a means for establishing the date of manufacture.

NOTE X1.10—In many cases, the qualified certification agency also conducts plant inspections. Therefore, the labeling may only show the qualified certification agency.

X1.6.3 Product certification shall include a product evaluation report accessible by building officials and the general public. The report shall provide design properties determined in accordance with these criteria and the applicable building codes.

X2. COMMENTARY ON LIMITATIONS OF APPLICABILITY AND POSSIBLE END-USE CONSIDERATIONS

X2.1 Scope

X2.1.1 Appendix X2 discusses the need for limiting the applicability of this specification to materials corresponding to the descriptions of 3.2 and the need for carefully devised and controlled manufacturing procedures.

X2.1.2 Appendix X2 provides a partial list of considerations that may be important in end use. Included are design considerations and conditions that may affect both mechanical and physical properties. Standards that are helpful in evaluating these concerns are given.

X2.2 Limitations to the Applicability of This Specification

X2.2.1 The potential variety of wood-based structural composites is very great. The committee felt that the applicability of this specification should be limited to general composite types for which there is a reasonable body of technical knowledge. The strand length-to-thickness ratio (*l/t*) of 75 for OSL is based on commercial products currently available. The effect of the *l/t* ratio on strength of SCL is given in Ref **(24)**. It is intended that the descriptions of 3.2 be modified as the knowledge base expands. One example of such a modification is the addition of laminated veneer bamboo (LVB) to the standard. Though bamboo is not a "wood species," it contains cellulose microfibrils embedded in a matrix of lignin and hemicelluloses and has cellulose and lignin in the same percentage ranges as deciduous woods.

X2.2.2 Manufacturing variables will, of course, be reflected in the data generated by the investigations detailed in this specification, but there may be subtle effects not apparent. A particular concern brought before the committee was the importance of considering performance when load is applied for sustained time periods.

X2.2.2.1 Generally, it is expected that composites, as defined in this specification, will perform similarly to other wood structural members when subjected to load for sustained periods. However, it is possible that manufacturing procedures can adversely affect this performance **(25)**. Two manufacturing parameters suspected are: too low adhesive spread or erratic bond quality, and damage due to improperly controlled pressing (time/temperature) cycles. The experience of the SCL committee members to-date indicates that acceptable sustained-load performance in actual field applications has been observed for properly manufactured wood-based structural composites.

X2.2.2.2 The traditional wood member adjustment from test to basic (normal duration) design values is included in the factors of Table 1. For design, other adjustments are made as defined in 7.4.2. These factors were judged appropriate for use with properly manufactured materials covered by this specification provided the requirements of Specification D6815 are met.

X2.2.2.3 In conducting Specification D6815 testing, it was the committee judgement that the Duration-of-Load performance should be verified for the typical manufacturing process. The intent was not to test all production facilities or all changes in process variables such as press cycles, equipment changes, minor adhesive changes, individual species, and so forth. It is the responsibility of the manufacturer and the qualified agency to evaluate any limiting conditions in the manufacturing process.

X2.2.2.4 The committee's recommendation was to evaluate one representative grade per adhesive classification. Examples of adhesive classifications are: phenol-formaldehyde, phenol-resorcinol, isocyanate-based adhesives, and so forth. The intent of the committee was not to require Duration of Load testing for adhesive modifications within a classification. Evaluation of only one grade is necessary since Specification D6815 specifies that the load level for long-term load tests be based on the short-term strength of that grade.

X2.2.2.5 The committee further recommended that for products manufactured with one or more species, either separately or mixed, the greatest anticipated percentage(s) of the highest density species should be evaluated. This was based on the general trend toward greater difficulty in bonding wood species as wood density increases. There are however, other factors besides density that can affect the bonding of wood and Chapter 9 of the Wood Handbook **(3)** provides additional guidance in this area. Table 9-1 of the Wood Handbook **(3)** shows general categories of selected wood species according to their ease of bonding. Generally, testing conducted by most manufacturers has included at least one softwood and one hardwood species (where applicable). Additional evaluation is also considered necessary for those species not native to North America having bonding characteristics that are not well understood.

X2.2.2.6 The users of this specification are advised to carefully evaluate the entire manufacturing process of any SCL product for conformance with well-established procedures. When doubts exist, sustained-load tests at more stress levels and longer time periods should be conducted.

X2.2.2.7 Certain proprietary materials that conform to the descriptions of 3.2, have been subjected to time-under-load testing. Outlines of procedures that have been followed, and data summaries are given in Refs **(26-28)**.

X2.2.3 *SCL Adhesives:*

X2.2.3.1 *Bond Durability*—Binder Adhesives

The purpose of Annex A5 is to provide bond durability performance criteria for binder adhesives used to manufacture SCL products that fall within the scope of Specification D5456.

The qualification of the bond durability of binder adhesives intended for use in the manufacture of wood structural panels (WSP) is available in other U.S. (that is, PS2) and Canadian standards (CSA O325, O437.2). The required bond durability performance level for WSP sheathing, as established within its respective standards, is based upon an assumption that WSP products are typically supported by a series of repetitive structural members provided at a relatively close spacing (that is, wall stud, floor joist, roof rafter, etc.). Since SCL qualified to this standard may serve as the repetitive supporting member or be used in non-repetitive structural applications (that is, beam or column), the minimum bond durability performance level required in Annex A5 for binder-type SCL products was intended to surpass that required for WSPs.

As defined in this standard, SCL products manufactured with binder adhesives include laminated strand lumber (LSL) and oriented strand lumber (OSL). The current commercially available LSL and OSL are composed of: (i) wood strands, typically hardwoods, (ii) a binder adhesive that is either phenolic- or isocyanate-based, or both, and (iii) manufactured with a proprietary process that applies heat and pressure (that is, steam injection press, steam pre-heating, hot platens). These commercially available LSL and OSL products, with their respective wood furnish, binders and manufacturing process, have demonstrated a satisfactory level of structural performance for use conditions within the scope of this standard. Hence, the bond durability acceptance criteria set in Annex A5 has been calibrated to the bond performance level of the current LSL and OSL products. These performance criteria will now serve as a benchmark for future bond durability evaluations of binder adhesives.

X2.2.3.2 *Other Durability Requirements*—Binder Adhesives

Manufacturers of SCL and manufacturers of binder adhesives should note that the requirements in Annex A5 extend beyond the series of short-span shear tests specifically outlined. The Annex A5 tests were intended to supplement the series of durability tests already required by the main body of this standard (that is, creep/DOL, adhesive heat durability, thickness swell, product bending durability, and lateral edge nail durability). In addition, as detailed by A5.4, suitable binder adhesives must also demonstrate resistance to other potential degradation mechanisms (that is, fungal decay, bacteria, hydrolysis, etc.) as a pre-requisite requirement. Further durability screening tests or pre-requisite requirements, or both, may need to be considered for inclusion in this Standard as new classes of adhesives are developed in the future.

X2.2.3.3 *Relation to Structural Adhesive Standards*—The need for this SCL binder adhesive qualification procedure is due to the fact that binder adhesives cannot be evaluated in accordance with Specification D2559 or the CSA Standards for Wood Adhesives O112-M Series standards used for non-binder adhesives. Since the binder adhesives cannot be evaluated independent of the proprietary manufacturing process, it is the bond durability of the finished SCL product that is evaluated using Annex A5. The structural adhesive standards mentioned above are not designed to evaluate the LSL and OSL products.

X2.2.3.4 *Applicability to Non-binder SCL*—Structural adhesives used in the manufacture of LVL, PSL, and other SCL products that use non-binder adhesives should comply with the specified structural adhesive standard (ASTM D2559 and CSA Standards for Wood Adhesives O112-M Series) as a separate qualification. When additional data become available, the use of Annex A5 for SCL with non-binder adhesives may be considered by the committee.

X2.2.4 SCL products, such as LVL and PSL, have been successfully used for decades. One key to their broad acceptance has been the use of adhesives that provide performance under a range of moisture, temperature, or structural loading conditions that are equal to or better than the wood substrate. The structural and moisture durability aspects have long been addressed in Specification D2559 and CSA Standards for Wood Adhesives, O112-M Series.

X2.3 Design and Mechanical Property Concerns

X2.3.1 *Creep and Relaxation*—Creep and relaxation are a function of stress and environment, particularly moisture content and cyclic changes of moisture and should be considered in applications sensitive to long-term deformation or stress relaxation.

X2.3.2 *Moisture Service Environment*—If the material is to be used in other than a dry service environment, the performance of members used in other service conditions should be evaluated, including development of appropriate strength reduction factors.

X2.3.3 *Treating*—The performance of the material should be evaluated for the effect of preservative or fire-retardant chemicals and treating processes.

X2.3.4 *Temperature*—The performance of the material should be evaluated for the effect of temperature if the material is to be exposed to temperatures outside the range from −30 to 150°F (−34 to 65°C) for sustained periods.

X2.3.5 *Fire Resistance*—The performance of SCL material under fire conditions should be evaluated. Full-scale assembly tests may be required in accordance with Test Methods E119. Alternatively, material property tests may sometimes be substituted for full-scale tests.

X2.3.6 *Flame Spread*—When necessary, the flame spread of the composite material should be determined in accordance with Test Method E84.

X2.3.7 *Char Rate*—The char rate of the composite material can be determined in accordance with the method described in Ref **(29)**.

X2.3.8 *Flexure at Elevated Temperature*—The flexural strength of the composite material at elevated temperature can be evaluated by subjecting structural-sized specimens to temperatures of 500°F (260°C) under full design load. Measurements of deflection and time to failure should be made during the test, as well as a record of the temperature during the test.

X2.3.9 *Row Nailing*—Size, spacing, and penetration of nails aligned in a row can induce splitting of all lumber products at critical combinations of these variables. When row nailing of this critical nature is anticipated, tests should be conducted to determine limits for each orientation of the material involved.

X2.3.10 *Component Use*—The influence of the interaction between several members and the quality of fabrication should be considered in the adjustment of allowable design stresses for material intended for use in components. Components may include such structural forms as trusses or built-up sections. Built-up sections require consideration of volume effects in the cross section.

X2.3.11 *Other*—If the material will be subjected to other conditions for which the product performance is unknown, appropriate product testing should be conducted.

X2.3.12 *Compression Perpendicular-to-Grain*—The determination of the design stress, *S*, for compression perpendicular-to-grain for SCL was originally adapted from Practice D245 for lumber, which uses a divisor of 1.67 to adjust from the test basis (growth rings oriented parallel to the applied load) to the limiting design basis (growth rings at 45° angle relative to the applied force) (see Ref. **(8)** of Practice D245-06). The divisor, C_a, equal to 1.67 was conservatively applied to SCL for which ring angle strength reductions are not applicable.

In the judgment of the committee, compression perpendicular to the *L-X* (flatwise) plane, without reduction by the 1.67 adjustment factor, based on the lower of the average stress at 0.04 in. (1 mm) deformation or the average proportional limit stress is appropriate and consistent with a basic design approach for wood to ensure design stresses remain in the elastic range. Common applications for flatwise SCL include wall plates and flanges for prefabricated wood I-joists.

The average 0.04 in. (1 mm) deformation limit with divisor, C_a, equal to 1.67 remains the procedure for determination of design stresses for compression perpendicular to grain in the *L-Y* (edgewise) plane. While direct determination of proportional limit stress can be obtained for compression normal to the*L-Y* plane, the specimen size and loading conditions employed may not address potential failure modes associated with loading full size members and therefore the proportional limit approach and removal of the 1.67 divisor are not extended to the stresses in the*L-Y* plane.

Similarly for members fabricated from laminations of flatwise SCL, the likelihood of encountering failure modes not addressed by the compression perpendicular-to-grain design value increases as the overall height exceeds the width.

X2.4 Physical Properties and Standards

X2.4.1 *Electrical Conductivity/Dielectric Properties*—See Test Methods D150, D669, D2132, and D3755.

X2.4.2 *Thermal/Environmental Properties*—See Test Methods C177 and E96/E96M.

X2.4.3 *Acoustical Properties*—See Test Methods C384 and C423.

X2.4.4 *Hygroscopic Properties*—See Test Method D3201.

X2.4.5 *Coefficient of Friction*—See Test Methods D2394.

X2.4.6 *Machining*—See Test Methods D1666.

X3. EXAMPLE PROCEDURE TO DETERMINE SCL NAIL WITHDRAWAL AND DOWEL BEARING EQUIVALENT SPECIFIC GRAVITY VALUES

X3.1 Scope

X3.1.1 Appendix X3 provides example calculations for determining the equivalent specific gravity values for the range of dowel connectors and product orientations specified in this standard. The rules for combining results for different product orientations and load directions are consistent with those used to develop nail withdrawal and dowel bearing capacities for solid sawn lumber (**4, 30**). The data provided was chosen to illustrate the rules for combining results or equivalent specific gravity values.

X3.1.2 The results of withdrawal and dowel bearing tests conducted on an SCL product in accordance with procedures of Annex A2 are summarized in Tables X3.1 and X3.2.

X3.2 Determination of Withdrawal Equivalent Specific Gravity Values for Nails

X3.2.1 From Table X3.1 and *SG* values interpolated from Table 11.2C of Ref (**4**), the equivalent *SG* values in Table X3.3 were determined.

X3.2.2 Use the withdrawal design load in the NDS for SG_Y = 0.54 for the *Y*-orientation and SG_X = 0.50 for the *X*-orientation or use lower value (*SG* = 0.50) if one value is specified for both orientations.

X3.3 Determination of Dowel Bearing Equivalent Specific Gravity Values for Nail Connections

X3.3.1 From Table X3.2 and *SG* values interpolated from Table 11.3.2 of Ref (**4**), the equivalent *SG* values in Table X3.4 were determined.

X3.3.2 For the *Y* orientation, the individual dowel bearing strength results do not differ by more than 20 % of the average, therefore the equivalent *SG* is based on 6715 psi (46.3 N/mm^2) and SG_Y equals 0.61.

X3.3.3 For the *X* orientation, the individual dowel bearing strength results differ by more than 20 % of the average, therefore the equivalent *SG* is not based on the average strength but is based on the lower strength value of 4000 divided by 0.8 which yields 5000 psi (34.5 N/mm^2) and therefore the equivalent SG_X equals 0.52.

X3.4 Determination of Dowel Bearing Equivalent Specific Gravity Values for Bolted Connections

X3.4.1 From Table X3.2 and *SG* values interpolated from Table 11.3.2 of Ref (**4**), the equivalent *SG* values in Table X3.5 were determined.

TABLE X3.1 Nail Withdrawal Test Results

NOTE 1—1 in. = 25.4 mm; 1 lb = 4.448 N.

Nail Type	Dowel Diameter, in.	Penetration Depth, in.	Average Withdrawal Load, lb	
			Y Orientation	*X* Orientation
8d Common	0.131	1.25	250	200

TABLE X3.2 Dowel Bearing Test Results

NOTE 1—1 in. = 25.4 mm; 1 psi = 6894.8 N/mm^2.

Dowel Type	Dowel Bearing Strength, psi			
	Dowel in *Y* Orientation (perpendicular to glueline)		Dowel in *X* Orientation (parallel to glueline)	
	Loaded in:		Loaded in:	
	L Direction	*X* Direction	*L* Direction	*Y* Direction
10d Common Nail	7680	5750	6680	4000
½-in. Diameter Bolt	6840	3820	6400	2850
¾-in. Diameter Bolt	7050	3270	6600	2500

TABLE X3.3 Equivalent SG Values

NOTE 1—1 in. = 25.4 mm; 1 lb = 4.448 N.

Nail Diameter, in.	Nail Withdrawal Strength, lb					
	Nail in *Y* Orientation (perpendicular to glueline)			Nail in *X* Orientation (parallel to glueline)		
	Strength Per Inch of Penetration	Allowable Strength Per Inch	Equivalent SG_Y	Strength Per Inch of Penetration	Allowable Strength Per Inch	Equivalent SG_X
0.131 (8d Common)	200	40	0.54	160	32	0.50

X3.4.2 For the *Y* orientation, the individual equivalent *SG*s for each bolt diameter and load direction do not differ by more than 0.03 from the average equivalent SG_Y, therefore the equivalent SG_Y equals 0.60. Alternatively, the equivalent*SG* in the L direction (SG_{YL}) of 0.62 or the equivalent *SG* in the *X* direction (SG_{YX}) of 0.58 can be determined since their individual *SG*s do not differ by more than 0.03 from their respective average equivalent *SG*.

X3.4.3 For the *X* orientation, the individual equivalent *SG*s for each bolt diameter and load direction differ by more than 0.03 from the average equivalent SG_X, therefore the equivalent *SG* is determined as the lowest equivalent *SG* (0.47) plus 0.03 to give an equivalent SG_X equaling 0.50. Alternatively, the equivalent *SG* in the *L* direction (SG_{XL}) of 0.58 or the equivalent *SG* in the *Y* direction (SG_{XY}) of 0.48 can be determined since their individual *SG*s do not differ by more than 0.03 from their respective average equivalent *SG*.

X3.5 Determination of Equivalent Species Combination for Dowel-Type Fasteners

X3.5.1 The equivalent *SG* values determined in X3.2 – X3.4 are summarized in Table X3.6 along with the lower, nearest wood species combination group found in Table 11.3.2 of Ref (**4**).

X3.5.2 The equivalent species combination group for nail and screw fasteners is determined to be as follows:

X3.5.2.1 *Withdrawal—Y* orientation only: Mixed Southern Pine (*SG* = 0.51); *X* orientation only: Douglas Fir - Larch (*SG* = 0.50); and *Y* and *X* orientation combined: Douglas Fir - Larch (*SG* = 0.50).

TABLE X3.4 Dowel Bearing Strength for Nail Connections

NOTE 1—1 in. = 25.4 mm; 1 psi = 6894.8 N/mm^2.

Dowel Type	Dowel Bearing Strength, psi									
	Nail in *Y* Orientation (perpendicular to glueline)					Nail in *X* Orientation (parallel to glueline)				
	Strength in:			Equivalent SG_Y		Strength in:			Equivalent SG_X	
	L Direction	*X* Direction	Average	Based on Average Strength	Specified	*L* Direction	*Y* Direction	Average	Based on Average Strength	Specified
10d nail	7680	5750	6715	0.61	0.61[A]	6680	4000	5340	0.54	0.52[B]

[A] See X3.3.2.
[B] See X3.3.3.

TABLE X3.5 Dowel Bearing Strength for Bolted Connections

NOTE 1—1 in. = 25.4 mm; 1 psi = 6894.8 N/mm^2.

Dowel Diameter, in.	Dowel Bearing Strength, psi											
	Bolt in *Y* Orientation (perpendicular to glueline)						Bolt in *X* Orientation (parallel to glueline)					
	Strength in *L* Direction		Strength in *X* Direction		Equivalent SG_Y		Strength in *L* Direction		Strength in *Y* Direction		Equivalent SG_X	
	$Fe_{//}$	$SG_{//}$	$Fe_{\perp}$	$SG_{\perp}$	Average	Specified	$Fe_{//}$	$SG_{//}$	$Fe_{\perp}$	$SG_{\perp}$	Average	Specified
½	6840	0.61	3820	0.57	0.60	0.60[A]	6400	0.57	2850	0.47	0.53	0.50[B]
¾	7050	0.63	3270	0.59			6600	0.59	2500	0.49		
	Equivalent SG_{YL} = 0.62[A]		Equivalent SG_{YX} = 0.58[A]				Equivalent SG_{XL} = 0.58[B]		Equivalent SG_{XY} = 0.48[B]			

[A] See X3.4.2.
[B] See X3.4.3.

TABLE X3.6 Summary Equivalent SG Results

Fastener	Test	*Y* Orientation		*X* Orientation	
		Equivalent *SG*	Nearest Species Combination (*SG*)	Equivalent *SG*	Nearest Species Combination (*SG*)
Nail	Withdrawal	SG_Y = 0.54	Mixed Southern Pine (0.51)	SG_X = 0.50	Douglas Fir — Larch (0.50)
	Dowel Bearing	SG_Y = 0.61	Red Maple (0.58)	SG_X = 0.52	Mixed Southern Pine (0.51)
Bolt	Dowel Bearing	SG_Y = 0.60	Red Maple (0.58)	SG_X = 0.50	Douglas Fir — Larch (0.50)
		or	or	or	or
		SG_{YL} = 0.62	Red Maple (0.58)	SG_{XL} = 0.58	Red Maple (0.58)
		SG_{YX} = 0.58	Red Maple (0.58)	SG_{XY} = 0.48	Western Hemlock (0.47)

X3.5.2.2 *Dowel Bearing Strength—Y* orientation only: Red Maple (*SG* = 0.58); *X* orientation only: Mixed Southern Pine (*SG* = 0.51); and *Y* and *X* orientation combined: Mixed Southern Pine (*SG* = 0.51).

X3.5.3 The equivalent species combination group for dowel bearing strength for bolt and lag screw fasteners is determined to be: *Y* orientation only: Red Maple (*SG* = 0.58); *X* orientation only: Douglas Fir - Larch (*SG* = 0.50); and *Y* and *X* orientation combined: Douglas Fir - Larch (*SG* = 0.50). Alternatively for bolts, the individual equivalent species combination can be specified as shown in Table X3.6.

X4. LONGITUDINAL SHEAR STRENGTH ADJUSTMENT FACTOR FOR SCL BASED ON THE SHEAR BLOCK TEST METHOD

X4.1 Introduction

X4.1.1 Eq 2 of 7.3 includes an adjustment factor to arrive at a capacity considered appropriate for structural members produced and used under the provisions of this specification. Table 1 shows these adjustment factors and lists two factors for longitudinal shear strength, one based on a structural-size shear test and the other based on a shear block test. Appendix X4 provides an explanation of the longitudinal shear strength adjustment factor for SCL products based on the shear block test as defined in this specification.

X4.2 Explanation

X4.2.1 This explanation was prepared by Dr. S. K. Suddarth as a position paper, "Recommendations for Allowable Shear Stress Factors for Structural Composite Lumber from Test Data" dated June 11, 1987, and is part of the October 1987 meeting minutes. This position paper is summarized below but with some updated information.

X4.2.2 For sawn lumber, Practice D245, prior to 2000, specified that allowable shear stress is derived from a 5th percentile estimate of small, green, clear shear block strength divided by a factor of 4.1 (see the current edition of Practice D245 for current factor of shear). This factor was not broken down in Practice D245 and it appeared to emerge from earlier recommendations from the U.S. Forest Products Laboratory that shear strength be derived from the average value of the small, green, clear tests and dividing this average by 6.

X4.2.3 A 1979 study at the U.S. FPL (General Technical Report FPL 23, Evolution of Allowable Stresses in Shear, 1979, Ethington et al.) traced the history of the factor of 6 on the mean and indicates the origin of the related factor of 4.1 on the 5th percentile. Load duration for the 6 factor is "long term" while load duration for the 4.1 factor is "normal" (ten years).

X4.2.3.1 The factor of 6 was made up as follows:

(1) 4/3, variability adjustment.

(2) 16/9, load duration adjustment from test time to long term.

(3) 9/8, safety or end-use factor.

(4) 9/4, adjustment for stress concentration due to drying.

$$(4/3) \times (16/9) \times (9/8) \times (9/4) = 6 \quad \text{(X4.1)}$$

X4.2.3.2 Variability was treated separately and the factor of 4.1 was made up as follows:

(1) 16/9, load duration test—long term.

(2) 10/11, load duration tong term—ten years.

(3) 9/8, safety factor.

(4) 9/4, stress concentrations from drying.

$$(16/9) \times (10/11) \times (9/8) \times (9/4) = 4.1 \quad \text{(X4.2)}$$

X4.2.4 SCL is made of materials that already contain drying effects which, theoretically, would reduce the 9/4 stress concentration factor to 1. A more conservative approach recommended and adopted by the committee was to reduce the 9/4 to 3/2. It was also recommended and adopted that the safety factor be raised from 9/8 to 13/10 in keeping with the corresponding factors for tension and flexure. The required shear factor for SCL is, therefore:

$$(16/9) \times (10/11) \times (13/10) \times (3/2) = 3.15 \quad \text{(X4.3)}$$

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