Designation: D5574 – 94 (Reapproved 2021)

Standard Test Methods for Establishing Allowable Mechanical Properties of Wood-Bonding Adhesives for Design of Structural Joints[1]

This standard is issued under the fixed designation D5574; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the principles for establishing allowable mechanical properties for adhesives that can be used to design adhesive-bonded joints for structural components and assemblies of wood or wood with other materials. These test methods are modeled after Practice D245.

1.2 The properties determined are allowable shear stress, allowable tensile stress, and allowable shear modulus.

1.3 In determination of allowable shear- and tensile-stress levels, these test methods are limited by the horizontal shear and tension perpendicular-to-the-grain capacity of the wood adherends (hard maple, *Acer saccharum*, Marsh.). The adhesives so tested may actually have shear or tensile allowable stresses exceeding the wood, but the determined allowable design stress levels are limited (upper bounded) by the wood in these test methods. If a wood other than hard maple is used for testing the adhesive, then the allowable strengths are upper bounded by the properties of that particular wood.

1.4 The strength properties are determined by standard ASTM test methods. As a result, only procedural variations from the standards and special directions for applying the results are given in these test methods.

1.5 Time-to-failure data derived from creep-rupture testing (see Test Method D4680) provide a measure of the ultimate strength of an adhesive bond as a function of time at various levels of temperature and moisture.

1.5.1 With proper caution, useful service life at a given shear stress level may be extrapolated from relatively short loading periods.

1.6 The resistance of the adhesive to permanent loss of properties due to aging (permanence) is assessed by means of strength tests after constant elevated-temperature and moisture aging of test specimens.

1.6.1 If the subject adhesives will be used to bond wood that has been treated with a preservative, fire retardant, or any other chemical to modify its properties, then the permanence of the adhesive shall be tested using wood adherends treated in the same manner.

1.7 Factors for durability, permanence, and creep derived by shear tests and analysis, are assumed to apply to tension (normal-to-the-bond) strength as well.

1.8 Requirements for production, inspection, and certification of adhesives evaluated under these test methods are not included.

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 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]

D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

D897 Test Method for Tensile Properties of Adhesive Bonds

D905 Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading

D907 Terminology of Adhesives

D1101 Test Methods for Integrity of Adhesive Joints in Structural Laminated Wood Products for Exterior Use

D1151 Practice for Effect of Moisture and Temperature on Adhesive Bonds

D2555 Practice for Establishing Clear Wood Strength Values

D2559 Specification for Adhesives for Bonded Structural

[1] These test methods are under the jurisdiction of ASTM Committee D14 on Adhesives and are the direct responsibility of Subcommittee D14.70 on Construction Adhesives.

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

Wood Products for Use Under Exterior Exposure Conditions
D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
D3931 Test Method for Determining Strength of Gap-Filling Adhesive Bonds in Shear by Compression Loading
D3983 Test Method for Measuring Strength and Shear Modulus of Nonrigid Adhesives by the Thick-Adherend Tensile-Lap Specimen
D4027 Test Method for Measuring Shear Properties of Structural Adhesives by the Modified-Rail Test
D4502 Test Method for Heat and Moisture Resistance of Wood-Adhesive Joints
D4680 Test Method for Creep and Time to Failure of Adhesives in Static Shear by Compression Loading (Wood-to-Wood)
D4896 Guide for Use of Adhesive-Bonded Single Lap-Joint Specimen Test Results
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *allowable design stress, n*—a stress to which a material can be subjected under stated service conditions with low probability of mechanical failure within the design lifetime. **(D4896)**

3.1.1.1 *Discussion*—Allowable design stress is obtained by multiplying the basic stress by a safety factor and possibly one or more modification factors as required by the intended service environment.

3.1.2 *allowable shear stress, n*—in an adhesive-bonded joint, the allowable design stress for structural joints subjected to shear force.

3.1.3 *allowable tensile stress, n*—in an adhesive-bonded joint, the allowable design stress for structural joints subjected to tension force.

3.1.4 *creep rupture, n*—the fracture of a material resulting from a sustained stress (or sum of stresses) above the creep rupture limit.

3.1.4.1 *Discussion*—The material may experience creep through the primary, secondary, and tertiary stages of rupture.

3.1.5 *creep-rupture limit, n*—the stress level below which creep rupture will not occur within a given time in a specified environment. See *creep rupture*.

3.1.6 *durability, n*—as related to adhesive joints, the endurance of joint strength relative to the required service conditions. **(D907)**

3.1.6.1 *Discussion*—Service conditions may include water and other chemicals, temperature, stress, radiation, microorganisms, and other environmental factors.

3.1.7 *permanence, n*—the resistance of an adhesive bond to deteriorating influences. **(D907)**

3.1.8 *structural adhesive, n*—a bonding agent used for transferring required loads between adherends exposed to service environments typical for the structure involved. **(D907)**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *allowable shear modulus, n*—the modulus calculated in accordance with Section 14, that is used for the design of a structural joint.

3.2.2 *basic shear modulus, n*—the average shear modulus of 30 specimens fabricated and tested in accordance with 13.1.

3.2.3 *basic shear strength, n*—a near minimum value of the shear strength distribution determined as the one-sided lower confidence interval on the fifth percentile as determined in accordance with 7.1. (See lower 5 % tolerance limit.)

3.2.4 *basic tensile strength, n*—a near minimum value of the tensile strength distribution determined as the one-sided lower confidence interval on the fifth percentile as determined in accordance with 9.1. (See lower 5 % tolerance limit.)

3.2.5 *creep factor, n*—for modulus, the monotonic modulus as a function of loading rate expressed as the decimal fraction of the basic modulus.

3.2.6 *creep factor, n*—for strength, the estimated 30 year creep rupture limit as a decimal fraction of the basic strength.

3.2.7 *delamination factor, n*—a pass/fail factor based on the percentage of delamination on the end grain of a laminate after cyclic delamination treatment.

3.2.7.1 *Discussion*—The factor is 0 or l: 0 if end-grain delamination is greater than 10 % of total end-grain bondline; 1 if less than 10 % after cyclic soak-dry treatment.

3.2.8 *durability factor, n*—the average strength under elevated test conditions expressed as a decimal fraction of the strength at standard condition.

3.2.8.1 *Discussion*—Increases in temperature and moisture level usually lower strength temporarily, as long as the specimen is not so weakened that fracture occurs. Decreases in temperature and moisture level usually increase strength. Exceptions occur when increasing the temperature raises the level of adhesive cure and strength, or decreasing the temperature or moisture induces brittleness and stress concentrations.

3.2.9 *lower 5 % nonparametric tolerance limit [NTL], n*—an estimate of the one-sided lower confidence bond on the fifth percentile of the strength distribution determined as the lowest ranked value (fast order statistic) of sample of specimens from a population.

3.2.10 *lower 5 % parametric tolerance limit [PTL], n*—an estimate of the lower confidence bound on the fifth percentile of the strength distribution calculated as the mean of a sample minus the sample standard deviation multiplied by a confidence level factor.

3.2.11 *lower 5 % tolerance limit, n*— an estimate of the one-sided lower confidence bound on the fifth percentile of the strength distribution of a population of specimens.

3.2.12 *modification factor, n*—any external or internal factor of the service environment that temporarily or permanently alters the strength or stiffness of an adhesive.

3.2.13 *multiaxial stress, n*—stress in two or three perpendicular directions, bi- or triaxial stress.

3.2.13.1 *Discussion*—In most wood structures bonded with

structural adhesives, multiaxial stress consists of a shear stress in the plane of, and tension stress normal to the plane of the adhesive layer.

3.2.14 *permanence factor, n*—the estimated residual strength at 30 years expressed as a decimal fraction of the original strength at standard conditions.

3.2.14.1 *Discussion*—This factor accounts for permanent, usually long-term, changes in strength or modulus due to the effects of factors such as heat, moisture, chemicals, ultraviolet light, and biological agents.

3.2.15 *safety factor, n*—a reduction factor to account for uncertainty in establishing an allowable design stress.

3.2.15.1 *Discussion*—The safety factor accounts for possible differences between laboratory and end-use conditions, differences in adhesive production lots, bonding variables, and the assumption that there is no interaction between modification factors.

4. Summary of Test Methods

4.1 These test methods are based on a conservative estimate of the near minimum value of the distribution of adhesive strengths measured by a standard test method. The basic strength of the adhesive is the lower 5 % nonparametric tolerance limit obtained by a sample of 59 specimens. The allowable design stress is the basic strength reduced by a safety factor as a minimum:

$$\textit{allowable design stress} = \textit{basic strength} \times \textit{safety factor}$$

The allowable shear modulus is the mean modulus of a group of specimens measured by a standard test method and adjusted by modification factors similar to those for strength as required by the service environment.

4.2 The allowable design stress (or modulus) can be modified by one or more modification factors that are appropriate for the intended-service exposure of the adhesive.

4.3 The modification factors used in these test methods are durability, permanence, delamination, and creep.

4.3.1 Temperature and moisture are the principal variables of both the durability and permanence factors. Chemicals, such as preservatives or fire retardants, may constitute a third element of the durability and permanence factors. These factors are shown in Appendix X1. Stress level and time, in addition to temperature and moisture, are important elements of the creep favor. Chemicals may be important to the creep factor if they plasticize or otherwise soften the adhesive. Cyclic gradients of moisture and temperature are principal elements of the delamination factor.

4.3.2 Modification factors are derived from standard test methods and specimens under critical-use conditions such as extreme temperature, moisture, chemical, or stress levels expected in service.

4.4 Flow charts showing tests and calculations required to establish allowable shear stress, allowable tensile stress perpendicular to bond, and allowable shear modulus for a given adhesive are shown in Appendix X2.

NOTE 1—The sequence described in the procedure sections of these test methods are not absolute. The delamination factor sets a pass/fail criteria for a given adhesive for exterior wet-use applications. If there is any doubt that the adhesive will pass the delamination requirement, the user can conduct this test before all others in order to save the expense of conducting the other tests needlessly.

5. Significance and Use

5.1 Safe and reliable mechanical properties for adhesives are necessary to achieve the full structural benefit of adhesives in bonded structural components and assemblies.

5.2 An adhesive's properties exhibit a natural variation or distribution of values. The allowable design stress for an adhesive must be adjusted to allow for variability and environmental effects to ensure human safety and prevent premature failure of costly structures.

5.3 Modification factors can be applied to the allowable design stress by the design engineer as deemed appropriate for the expected service conditions of the adhesive, or in accordance with the requirements of a building code.

5.4 The allowable properties developed under these methods apply only to the actual adhesive formulation tested and analyzed.

5.5 The allowable properties developed for a given adhesive shall apply only to adhesive bondlines with thicknesses in the range for which data is available.

6. Adhesive and Wood Preparation

6.1 Obtain a representative sample from each lot of adhesive to be tested.

6.1.1 For liquid or paste adhesives, take a sample from each lot of at least 1 qt (446 mL).

6.1.2 For adhesives consisting of more than one part, take a sufficient sample of each part to prepare at least 2 lb (908 g) of adhesive at the time of test-specimen fabrication.

6.1.3 For dry adhesives, take a sample from each lot weighing at least 1 kg (1.1 lb).

6.2 Follow the adhesive manufacturer's specifications for proper packing, mixing, and handling of the sample.

6.3 Follow the adhesive manufacturer's instructions for proper use of the adhesive. The information needed will vary for different types of adhesive. Important information may include:

6.3.1 The acceptable moisture-content range for the wood.

6.3.2 Complete mixing directions for the adhesive.

6.3.3 The acceptable range of conditions for adhesive application, such as rate of spread, thickness of wet film, bead size, number of coats to be applied, minimum temperature for application, single or double spread, and conditions for drying where more than one coat is required.

6.3.4 The acceptable range of open- and closed-assembly time over the ambient temperature and humidity range specified.

6.3.5 The acceptable range of curing conditions, including the pressure to be applied, if any; whether this pressure may be provided by nails or staples, or both, or by other means; the minimum time under pressure and the minimum temperature of the assembly when under pressure. It should be stated whether