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Standard Guide for Evaluating Mechanical and Physical Properties of Wood- Plastic Composite Products¹

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1. Scope

1.1 This guide covers test methods appropriate for evaluating a wide range of performance properties for wood-plastic composite (WPC) products. It was developed from evaluations of both experimental and currently manufactured products, and is not intended to suggest that all the tests listed are necessary or appropriate for each application of a WPC. The user must determine which test methods apply to the particular application being evaluated (see [Appendix X1](#)).

1.2 Details of manufacturing processes may be proprietary and are beyond the scope of this guide.

1.3 *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.*

2. Referenced Documents

2.1 ASTM Standards:²

- [C1308](#) Test Method for Accelerated Leach Test for Diffusive Releases from Solidified Waste and a Computer Program to Model Diffusive, Fractional Leaching from Cylindrical Waste Forms
- [D9](#) Terminology Relating to Wood and Wood-Based Products
- [D143](#) Test Methods for Small Clear Specimens of Timber
- [D792](#) Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- [D883](#) Terminology Relating to Plastics
- [D1037](#) Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials
- [D1038](#) Terminology Relating to Veneer and Plywood

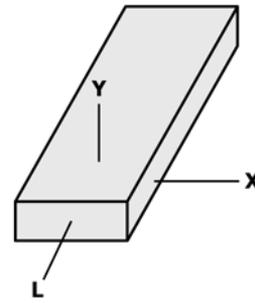
- [D1413](#) Test Method for Wood Preservatives by Laboratory Soil-Block Cultures
- [D1554](#) Terminology Relating to Wood-Base Fiber and Particle Panel Materials
- [D1761](#) Test Methods for Mechanical Fasteners in Wood
- [D1929](#) Test Method for Determining Ignition Temperature of Plastics
- [D2017](#) Test Method of Accelerated Laboratory Test of Natural Decay Resistance of Woods (Withdrawn 2014)³
- [D2047](#) Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine
- [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
- [D2481](#) Test Method for Accelerated Evaluation of Wood Preservatives for Marine Services by Means of Small Size Specimens (Withdrawn 2014)³
- [D2565](#) Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
- [D2915](#) Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
- [D3345](#) Test Method for Laboratory Evaluation of Wood and Other Cellulosic Materials for Resistance to Termites
- [D4000](#) Classification System for Specifying Plastic Materials
- [D4060](#) Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- [D4092](#) Terminology for Plastics: Dynamic Mechanical Properties
- [D4442](#) Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
- [D4495](#) Test Method for Impact Resistance of Poly(Vinyl Chloride) (PVC) Rigid Profiles by Means of a Falling Weight
- [D4761](#) Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material
- [D5379/D5379M](#) Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

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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.

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



L direction - Parallel to the longitudinal direction of the member (length)
 X direction - Parallel to the wide surface of the member and normal to the L direction (width)
 Y direction - Normal to both the L and X direction (thickness)

FIG. 1 Orientation for Wood-Plastic Composites

- D5456 Specification for Evaluation of Structural Composite Lumber Products
- D5764 Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood-Based Products
- D6109 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastic Lumber and Related Products
- D6341 Test Method for Determination of the Linear Coefficient of Thermal Expansion of Plastic Lumber and Plastic Lumber Shapes Between -30 and 140°F (-34.4 and 60°C)
- D6662 Specification for Polyolefin-Based Plastic Lumber Decking Boards
- E84 Test Method for Surface Burning Characteristics of Building Materials
- E108 Test Methods for Fire Tests of Roof Coverings
- E661 Test Method for Performance of Wood and Wood-Based Floor and Roof Sheathing Under Concentrated Static and Impact Loads
- E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
- F1679 Test Method for Using a Variable Incidence Tribometer (VIT) (Withdrawn 2006)³
- G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
- 2.2 AWPAs Standards:⁴
 - AWPA Standard E1 Standard Method for Laboratory Evaluation for Determination of Resistance to Subterranean Termites
 - AWPA Standard E7 Standard Method for Evaluating Wood Preservatives by Field Tests with Stakes
 - AWPA Standard E10 Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Cultures

3. Terminology

3.1 *Definitions*—Terminology used to describe WPCs is defined in Terminology D9, D883, D1038, D1554, D4092, and Classification D4000.

3.2 *Definitions of Terms Specific to this Standard:*

3.2.1 *recycled products*—products composed of post-consumer material or recovered material, or both, that may or may not have been subject to additional processing steps of the types used to make the products.

3.2.2 *thickness*—the lesser dimension perpendicular to the long axis.

3.2.3 *virgin material*—a material that has not been subjected to use or processing other than that required for its initial manufacture

3.2.4 *width*—the greater dimension perpendicular to the long axis.

3.2.5 *wood-plastic composite (WPC)*—a composite made primarily from wood- or cellulose-based materials and plastic(s).

3.3 *Orientation*—WPCs have three principal directions (see Fig. 1).

⁴ Available from American Wood-Preservers' Association (AWPA), P.O. Box 388, Selma, AL 36702-0388, <http://www.awpa.com>.

4. Significance and Use

4.1 WPCs are intended for use in both structural and non-structural applications. The test methods described within are intended to address products that are manufactured from virgin or recycled wood and thermoplastic sources. These methods provide a reference for the evaluation of several mechanical and physical properties important for structural and non-structural uses of WPCs.

5. Determination of Mechanical and Physical Properties

5.1 The following mechanical and physical properties are included to provide a complete set of reference tests for a broad range of users. Some applications of WPCs will not require assessment of all properties. For example, products that will be limited to flexural applications will not require assessment of tension or compression properties.

5.2 *Sampling*—Samples for testing shall be representative of the population being evaluated. Sampling shall be conducted in accordance with applicable portions of Practice D2915 and be representative of the possible variations due to changes in raw materials and process variables over time. It is essential to consider batch-to-batch and shift-to-shift variability when sampling actual production. Test specimens shall be selected from several production runs of a given item.

5.3 *Sample Size*—Selection of a sample size depends upon the property to be estimated, the actual variation in the property occurring in the population, and the precision with which the property is to be estimated. The principles of Practice D2915 shall be followed.

NOTE 1—If code listed allowable design values or performance ratings are the objective, it is recommended that all sampling and testing be conducted or witnessed, or both, by a qualified inspection agency.

5.4 *Conditioning*—Prior to testing, all specimens shall be conditioned to environmental conditions appropriate for the intended end use of the product.

5.4.1 When temperature and relative humidity are important considerations, the test specimens shall be conditioned for a period of time such that the average daily mass change of the test specimen is less than 2 % of the mass at time of measure.

5.4.2 When the product is to be subjected to a water soak environment, the test specimens shall be tested within 30 min upon removal from the treatment.

5.5 *Bending*—Modulus of rupture (*MOR*) or moment capacity and apparent modulus of elasticity (*E*) or flexural stiffness shall be determined in accordance with principles of Test Methods **D4761** or **D6109**. For some applications and products, moment capacity and flexural stiffness are preferable performance measures. Whenever possible, the test specimen shall be the full cross section of the as-manufactured product. Selection of specimen dimensions establishes the unit volume for analysis of volume effects in accordance with Specification **D5456**, when applicable. A span-to-depth ratio of not less than 16 shall be used. The specimens shall be loaded at a constant strain rate of 1 % per minute ($\pm 10\%$). Average time to failure for each test configuration shall be recorded (see **X1.5**). A constant strain rate of 1 % per minute is achieved by using a constant rate of test machine cross-head motion, *R*, (inches/minute) computed in terms of the test span, *L*, and the member depth, *d*, by the following equation:

$$R = 0.00185 \times \frac{L^2}{d}$$

NOTE 2—WPCs often exhibit exceptionally large deformations prior to failure in bending. Users are cautioned to take particular care in test machine set-up to accommodate large deflections, both in terms of deflection measuring devices and support conditions.

5.5.1 *MOR*—Maximum load for the calculation of *MOR* shall be reported for each specimen. If the calculation is based on a load other than the maximum load, the load basis shall be reported.

NOTE 3—For products that exhibit large deformations, the *MOR* value is commonly based on the load at 3 % strain.

5.5.2 *E*—Apparent flexural modulus of elasticity and its calculation basis shall be reported for each specimen. Characterization of the modulus of elasticity depends upon the use of the data. For material property information, *E* can be calculated in a variety of ways. For design value assignment purposes linear least squares fit of the stress-strain curve over an appropriate range of stress shall be used.

NOTE 4—To assign design values to structural members the least squares fit over a range of 10 to 40 % of ultimate stress is commonly chosen as representative for service loadings. An alternative calculation method based on the secant modulus to 1 % strain is commonly used for all-plastic products.

5.6 *Tension Parallel to the L Direction*—Tension strength parallel to the *L* direction shall be evaluated by testing in accordance with the principles of Test Methods **D4761**. Specimen cross section shall not be less than the minimum anticipated structural size. Specimen length between grips shall be a minimum of 12 times the actual test specimen width. The specimens shall be loaded at a constant strain rate of 1 % per minute ($\pm 10\%$). Average time to failure for each test configuration shall be recorded. If required, selection of specimen dimensions establishes the unit volume for the analysis of volume effects per Specification **D5456**.

5.7 *Compression Parallel to the L Direction*—Short column compression strength parallel to the *L* direction shall be

determined in accordance with the principles of Test Methods **D4761**. Tests shall be conducted on a cross section no less than the minimum anticipated structural size. Length of the specimen shall be such that *l/d* is less than 4.5 and greater than 3.0, where *l* is the effective unsupported length and *d* is the minimum cross-sectional dimension. For non-solid cross-section materials, the actual cross-sectional area shall be calculated.

5.8 *Compression Perpendicular to the L Direction*—Compression strength perpendicular to the *L* direction shall be determined following the measurement and bearing requirements of Test Method **D143**, except that the specimen dimensions shall be the full cross-section dimension of the WPC, and the length shall be three times the depth. Load shall be applied through a metal bearing plate across the full width of the test specimen. Stress at both 0.02 and 0.04 in. (0.5 and 1.0 mm) of deformation shall be reported. Testing shall be conducted with stresses applied normal to the *L-X* or *L-Y* plane, or both, when required for general product application. The objective of this test is to determine the load carrying capacity of the as-manufactured product. The allowable stress derived from this test will only apply to the actual cross section tested.

5.9 *Shear Strength:*

5.9.1 *Shear Parallel to the L Direction (Longitudinal Shear)*—Shear strength parallel to the *L* direction shall be determined in accordance with the principles of Test Method **D143** using the shear block test. Testing shall be done to produce shear failure in the *L-X* or *L-Y* plane, or both. For solid cross-section products, a minimum dimension of 1.0 in. (25 mm) in the shear area is acceptable provided that the total shear area is at least 1.0 in². For non-solid cross-section products, the full cross section shall be tested using the shear block tests with the actual shear area based on wall thickness(s) subjected to the shearing stress.

5.9.2 *Shear Perpendicular to the L Direction*—Shear strength perpendicular to the *L* direction shall be determined in accordance with the principles of Test Method **D143** using the shear block test. The Test Method **D143** shear block test has been shown to provide a conservative estimate of the shear strength of wood-based materials. Other test methods may be applicable. Testing shall be done to produce shear failure in the *X-Y* plane. For solid cross-section products a minimum dimension of 1.0 in. (25 mm) in the shear area is acceptable provided that the total shear area is at least 1.0 in².

NOTE 5—For non-solid cross-section products, a shear block test perpendicular to the *L* direction may not be practical. For some special cases, such as nonhomogeneous materials or non-solid cross-section products, alternative test methods such as Test Method **D5379/D5379M**, will provide additional insight into actual shear strength material properties.

5.10 *Creep-Recovery and Creep-Rupture:*

NOTE 6—When building code listed design values are the objective of the investigation, consideration of creep-recovery and creep-rupture are generally required.

5.10.1 *Creep-Recovery*—A minimum of ten specimens representative of the population being sampled shall be loaded in flexure in accordance with **5.5** to a bending stress appropriate

for the intended end use. The test specimens are loaded for 24 h, unloaded, and allowed to recover with no load for 24 h. Deflection at mid-span is measured a minimum of four times: (1) prior to the application of load, (2) at 24 h with load on, (3) within one minute after the load is removed, and (4) after the 24-h recovery period. Total deflection is the amount of deflection that occurred during the first 24-h period. The percent recovery for each test specimen is defined as the recovered deflection times 100, divided by the total deflection. The average percent recovery, rounded to the nearest percent shall be reported.

5.10.2 Creep-Rupture—A minimum of ten specimens representative of the population being sampled shall be loaded in flexure in accordance with 5.5 to a stress level appropriate for the intended end use. Prior to loading, the test specimens shall be allowed to equilibrate to the test temperature conditions (for example, $68 \pm 4^\circ\text{F}$ ($20 \pm 2^\circ\text{C}$)) and be maintained throughout the experiment. The load shall be maintained for a minimum of 90 days with deflection measurements taken at regular intervals to adequately describe the creep curve. It is recommended that for the first eight hours, measurements be taken hourly, for the following 24 h, measurements at eight-hour intervals are suggested, followed by daily measurements for the next seven days. Weekly measurements should be adequate for the remainder of the 90-day period unless there is evidence of tertiary creep (increasing creep rate).

NOTE 7—It is recognized that maintaining a constant temperature for a long period of time may be difficult. It is, therefore, recommended that temperature be recorded with a frequency sufficient to establish the magnitude and duration of temperature fluctuations.

5.11 Mechanical Fastener Holding Tests—When testing WPC materials for fastener holding properties, the principles of Test Methods **D1037**, **D1761**, or **D5764** shall be followed with the following exception: conditioning of the test material prior to specimen preparation shall be conducted in accordance with 5.4. Testing with nails, screws, and staples, when required, shall be performed in accordance with Test Methods **D1037** or **D1761**. Testing with bolts, when required, shall be in accordance with Test Method **D5764**.

NOTE 8—The procedures of Annex A2 on Establishing Equivalent Sawn Lumber Species Connection Properties for SCL of Specification **D5456** have been accepted by model code evaluation services for WPCs as an alternative method of establishing connection properties.

5.12 Impact Resistance—Depending upon the objective of the testing program, Test Methods **D4495** or **E661** shall be used to determine the impact resistance of WPCs. When required for a specific product application, this test shall be conducted on each surface where impacts are possible in service. The diameter of the impact weight in Test Method **D4495** shall be 1.0 in. (25 mm) producing a contact area of 0.785 in².

NOTE 9—For non-solid cross-section materials, the impact strength may be measured at several locations on the surface to determine the effect of the cross-section geometry.

5.13 Fire Performance:

5.13.1 Flame spread shall be determined using Test Method **E84**.

5.13.2 Other fire performance properties may be determined using Test Methods **E1354** or **D1929**, as appropriate. These test

methods provide an assessment of one or more of the following properties: smoke release rate, mass loss rate, heat release rate, and ignition temperatures.

5.14 Specific Gravity—Specific gravity specimens may be taken from an undamaged portion of each bending test specimen and measured in accordance with Test Method **D2395** or **D792**.

5.15 Moisture Content—Moisture content shall be measured in accordance with Test Method **D4442**. Using the specific gravity specimens (from 5.14) to measure moisture content is permissible.

5.16 Slip Resistance—The coefficient of friction shall be determined in accordance with accepted test methods. Test Method **F1679** has proven to be useful for this purpose. Alternatively, Test Method **D2394** and **D2047** have long been used as a historical benchmark. Wet and dry slip resistance both parallel and perpendicular to the *L* direction shall be evaluated.

NOTE 10—Choice of an appropriate test method depends on the specific needs of the end user. Recently developed methods are usable both in the laboratory and under a range of field conditions, and are believed to provide more reliable friction property estimates than historical methods.⁵ ASTM is currently coordinating slip resistance specification issues at the Society level. The results of this effort, when available, will be incorporated into this document. See **Appendix X1** for additional discussion.

5.17 Abrasion—Test Methods **D2394** or **D4060** shall be used to compare wear properties to solid wood.

5.18 Thermal Expansion—The procedures specified in Test Method **D1037** for linear expansion of panel products shall be used to determine the thermal dimensional change characteristics of the as-manufactured product. The temperature range evaluated shall represent typical in-service conditions. A minimum of ten (10) full cross-section test specimens, no less than 12 inches in length, shall be cut from the actual product. The test specimens shall be equilibrated to a reference condition (for example, $68 \pm 4^\circ\text{F}$ ($20 \pm 2^\circ\text{C}$)). A minimum of one length, width, and thickness measurement for each test specimen shall be recorded. The specimens shall be placed in a temperature controlled chamber at the desired temperature (higher or lower) and allowed to equilibrate. The dimensions for each test specimen shall be measured and recorded within 2 min after removal from the chamber. Care shall be taken to assure that subsequent measurements are taken at exactly the same location as the previous measurement. The deformation measuring equipment shall have an accuracy of ± 0.001 in. (± 0.025 mm). When comparing the thermal expansion properties of various products, the user is alerted to the potential influence of Poisson's effect for different materials. Therefore, it is recommended that test specimen aspect ratio be consistent. Alternatively, Test Method **D6341** shall be permitted.

5.19 Moisture Absorption, Thickness Swell—Test Method **D1037** shall be used to determine the moisture absorption and thickness swell properties of WPCs. The test specimens shall be prepared using the full cross section of the as-manufactured

⁵ Flynn, J.E. and Underwood, D., "Summary: Spring 1998 V.I.T. (English XL)," Round Robin, 1998