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Standard Guide for Evaluating Mechanical and Physical Properties of Wood-Plastic Composite Products[1]

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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

D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer

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

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 Specific Gravity of Wood and Wood-Based Materials

D2481 Test Method for Accelerated Evaluation of Wood Preservatives for Marine Services by Means of Small Size Specimens

D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications

D2915 Practice for Evaluating Allowable Properties for Grades of Structural Lumber

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-Base 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

D5456 Specification for Evaluation of Structural Composite Lumber Products

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

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

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
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)[3]
G154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

2.2 *AWPA 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

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

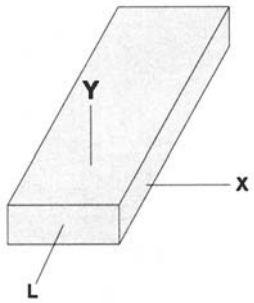
3.2.4 *width*—the greater dimension perpendicular to the long axis.

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. 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.



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

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

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from American Wood-Preservers' Association (AWPA), P.O. Box 388, Selma, AL 36702-0388, http://www.awpa.com.

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 (±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 (±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 in^2. 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 in^2.

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 ± 4°F (20 ± 2°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 7 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 in^2.

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. This information can be used to estimate the physical gap required between WPC components to allow for thermal expansion. The temperature range used shall represent typical in-service conditions. Alternatively, comparable Test Method D696 procedures are 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 product. Test conditions often used include submersion in water or exposure to high humidity conditions. Submersion time, or the duration the product is subjected to a high humidity environment, shall be representative of in-service conditions.

5.20 *Freeze-Thaw Resistance*—To determine the effect of freeze-thaw exposure, a minimum of three specimens shall be subjected to the cycle described below. Whenever possible, the test specimens shall be prepared using the full cross-section of the as-manufactured product. Test specimens shall be submerged underwater (using weights to hold them down, if necessary) for a period of 24 h. The specimens shall then be placed in a freezer set at -20°F (-29°C) for 24 h. After being subjected to freezing, the specimens shall be returned to room temperature for a period of 24 h. This process comprises one hygrothermal cycle. The above procedure shall be repeated two more times, for a total of three cycles of water submersion, freezing, and thawing. After completion of a minimum of three freeze-thaw cycles, the specimens shall be allowed to return to room temperature followed by flexure testing as described in Test Methods D4761 or D6109.

5.21 *Biodeterioration*—Test methods appropriate for the intended application shall be selected from the list below.

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